IEC 62282-4-101

Edition 2.0 2022-08
REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

Fuel cell technologies –
Part 4-101: ~~Fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU) – Safety of electrically powered industrial trucks~~
Fuel cell power systems for electrically powered industrial trucks – Safety

IEC 62282-4-101:2022-08 RLV(en)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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FUEL CELL TECHNOLOGIES –

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FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 62282-4-101:2014. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 62282-4-101 has been prepared by IEC technical committee 105: Fuel cell technologies.

This second edition cancels and replaces the first edition published in 2014. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) revision of the title of this document;
b) revision of reference standards;
c) addition of new subclauses (4.3, 4.14.5, 4.15.3, 4.15.4, 4.16, 5.6, and 5.23);
d) previous 4.15 was revised as “4.16 Risk assessment and risk reduction”;
e) revision of 4.6 3), access to the manual shutoff valve;
f) revision of requirements for battery terminals that are threaded (4.14.10.1);
g) revision of requirements for double layer capacitors (4.14.10.2);
h) revision of external leakage test (5.5) and ultimate strength test (5.7);
i) revision of temperature limits on capacitors depending on the temperature rating of the material (Table 3);
j) revision of markings that are not relevant (Clause 7);
k) added “Significant hazards, hazardous situations and events dealt with in this document” as a new informative annex (Annex B).

The text of this International Standard is based on the following documents:

Draft	Report on voting
105/912/FDIS	105/922/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts of IEC 62282 series, published under the general title *Fuel cell technologies*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The IEC 62282-4 series deals with categories such as safety, performance and interchangeability of fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU). Among the categories mentioned above, this document, IEC 62282-4-101, focuses on safety of electrically powered industrial ~~electric~~ trucks with fuel cell power systems because such applications are urgently demanded in the world. Future documents in this part of IEC 62282-4 will deal with other applications related to onboard vehicles other than road vehicles and auxiliary power units (APU).

FUEL CELL TECHNOLOGIES –

Part 4-101: ~~Fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU) – Safety of electrically powered industrial trucks~~ Fuel cell power systems for electrically powered industrial trucks – Safety

1 Scope

This document deals with safety of fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU).

This part of IEC 62282 covers safety requirements for fuel cell power systems intended to be used in electrically powered industrial trucks as defined in ISO 5053-1, except for:

– rough-terrain trucks;
– non-stacking low-lift straddle carriers;
– stacking high-lift straddle carriers;
– rough-terrain variable-reach trucks;
– slewing rough-terrain variable-reach trucks;
– variable-reach container handlers;
– pedestrian propelled trucks.

~~This standard is limited to electrically powered industrial trucks and is applicable to material-handling equipment, e.g. forklifts.~~

This document applies to gaseous hydrogen-fuelled fuel cell power systems and direct methanol fuel cell power systems for electrically powered industrial trucks.

The following fuels are considered within the scope of this document:

– gaseous hydrogen;
– methanol.

This document covers the fuel cell power system as defined in 3.8 and Figure 1.

This document applies to DC type fuel cell power systems, with a rated output voltage not exceeding 150 V DC for indoor and outdoor use.

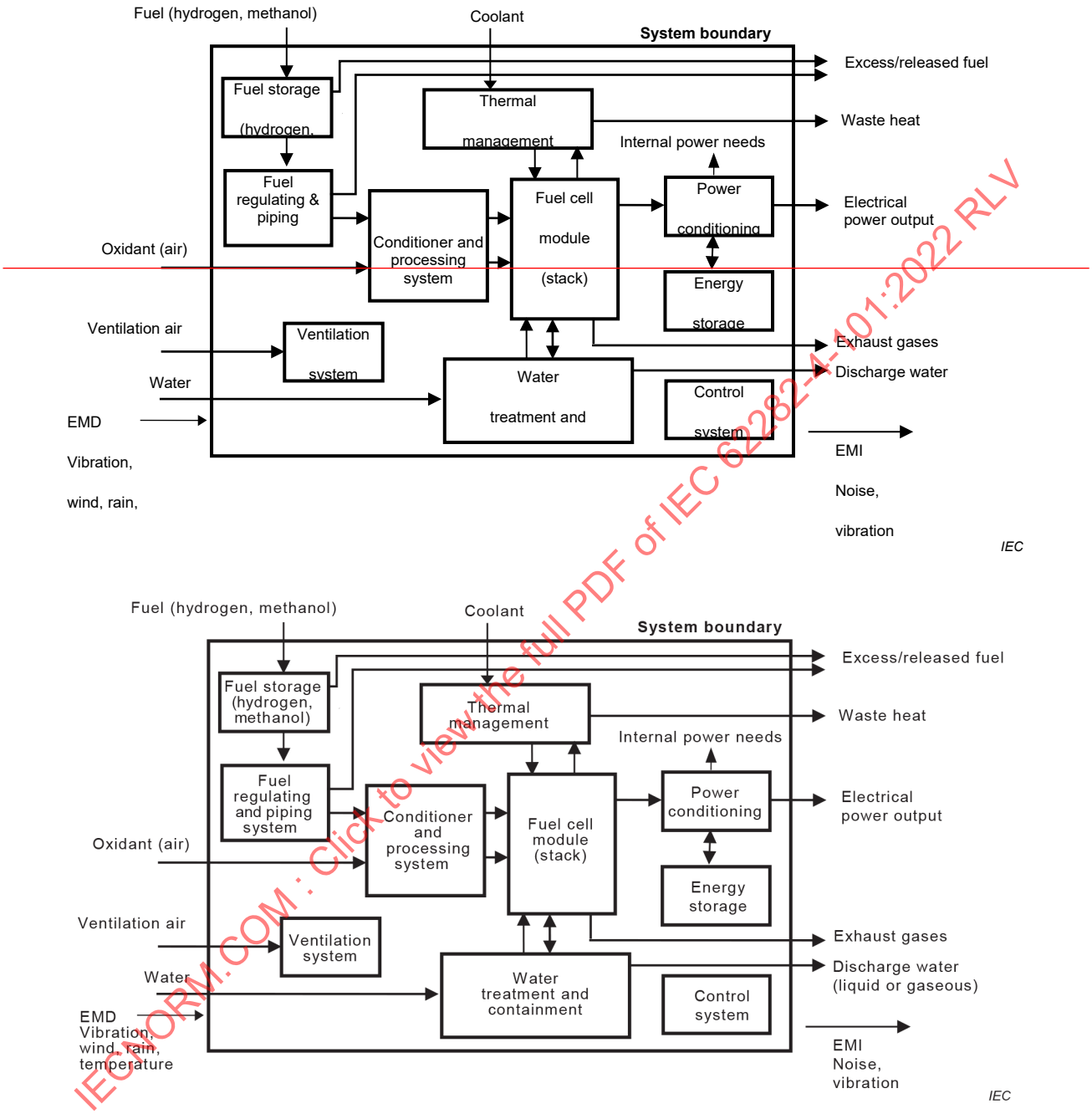
This document covers fuel cell power systems whose fuel source container is permanently attached to either the industrial truck or the fuel cell power system.

In accordance with IEC Guide 116, significant hazards, hazardous situations and events dealt with in this document are shown in Annex B.

The following are not included in the scope of this document:

– detachable type fuel source containers;
– hybrid trucks that include an internal combustion engine;
– reformer-equipped fuel cell power systems;

– fuel cell power systems intended for operation in potentially explosive atmospheres;
– fuel storage systems using liquid hydrogen.



Key

EMD electromagnetic disturbance

EMI electromagnetic interference

NOTE A fuel cell power system ~~may~~ can contain all or some of the above components.

Figure 1 – Fuel cell power systems for industrial trucks

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-485, *International Electrotechnical Vocabulary (IEV) – Part 485: Fuel cell technologies*

IEC 60079-0, *Explosive atmospheres – Part 0: Equipment – General requirements*

IEC 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

IEC 60079-29-1, *Explosive atmospheres – Part 29-1: Gas detectors – Performance requirements of detectors for flammable gases*

IEC 60079-29-4, *Explosive atmospheres – Part 29-4: Gas detectors – Performance requirements of open path detectors for flammable gases*

IEC 60204-1, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60227-3, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 3: Non-sheathed cables for fixed wiring*

IEC 60227-5, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 5: Flexible cables (cords)*

IEC 60335-2-41, *Household and similar electrical appliances – Safety – Part 2-41: Particular requirements for pumps*

IEC 60335-2-80, *Household and similar electrical appliances – Safety – Part 2-80: Particular requirements for fans*

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric* shock
IEC 60364-4-41:2005/AMD1:2017

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60584-1, *Thermocouples – Part 1: ~~Reference tables~~ EMF specifications and tolerances*

IEC 60664-1, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60695 (all parts), *Fire hazard testing*

IEC 60695-1-30, *Fire hazard testing – Part 1-30: Guidance for assessing the fire hazard of electrotechnical products – Preselection testing process – General guidelines*

IEC 60695-10-2, *Fire hazard testing – Part 10-2: Abnormal heat – Ball pressure test method*

IEC 60695-11-4, *Fire hazard testing – Part 11-4: Test flames – 50 W flame – Apparatus and confirmational test method*

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60730-1:2013, *Automatic electrical controls ~~for household and similar use~~ – Part 1: General requirements*
IEC 60730-1:2013/AMD1:2015
IEC 60730-1:2013/AMD2:2020

~~IEC 60730-2-17, *Automatic electrical controls for household and similar use – Part 2-17: Particular requirements for electrically operated gas valves, including mechanical requirements*~~

IEC 60812, *Failure modes and effects analysis (FMEA and FMECA)*

IEC 60947-3, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

IEC 60947-5-1, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

IEC 60950-1:2005, *Information technology equipment – Safety – Part 1: General requirements*
IEC 60950-1:2005/AMD1:2009
IEC 60950-1:2005/AMD2:2013

IEC 61025, *Fault tree analysis (FTA)*

IEC 61204-7, *Low-voltage switch mode power supplies~~, d.c. output~~ – Part 7: Safety requirements*

IEC TS 61430, *Secondary cells and batteries – Test methods for checking the performance of devices designed for reducing explosion hazards – Lead-acid starter batteries*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61558-1, *Safety ~~os power transformers, power supplies, reactors and similar products~~ of transformers, reactors, power supply units and combinations thereof – Part 1: General requirements and tests*

~~IEC 62103, *Electronic equipment for use in power installations*~~

IEC 62477-1, *Safety requirements for power electronic converter systems and equipment – Part 1: General*

IEC 62133-1, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications – Part 1: Nickel systems*

IEC 62282-2-100, *Fuel cell technologies – Part 2-100: Fuel cell modules – Safety*

IEC 62391-1, *Fixed electric double-layer capacitors for use in electric and electronic equipment – Part 1: Generic specification*

IEC 62391-2, *Fixed electric double-layer capacitors for use in electronic equipment – Part 2: Sectional specfication – Electric double layer capacitors for power application*

IEC 62619, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries, for use in industrial applications*

IEC/ISO 31010, *Risk management – Risk assessment techniques*

ISO 179 (all parts), *Plastics – Determination of Charpy impact properties*

ISO 180, *Plastics – Determination of Izod impact strength*

ISO 877 (all parts), *Plastics – Methods of exposure to solar radiation*

ISO 1419, *Rubber- or plastics-coated fabrics – Accelerated-ageing tests*

ISO 1421, *Rubber- or plastics-coated fabrics – Determination of tensile strength and elongation at break*

ISO 1798, *Flexible cellular polymeric materials – Determination of tensile strength and elongation at break*

ISO 2440, *Flexible and rigid cellular polymeric materials – Accelerated ageing tests*

ISO 2626, *Copper – Hydrogen embrittlement test*

ISO 3691-1, *Industrial trucks – Safety requirements and verification – Part 1: Self-propelled industrial trucks, other than driverless trucks, variable-reach trucks and burden-carrier trucks*

ISO/TS 3691-7, *Industrial trucks – Safety requirements and verification – Part 7: Regional requirements for countries within the European Community*

ISO/TS 3691-8, *Industrial trucks – Safety requirements and verification – Part 8: Regional requirements for countries outside the European Community*

ISO 3864-1, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs and safety markings*

~~ISO 3996, *Road Vehicles – Brake hose assemblies for hydraulic braking systems used with a non-petroleum-base brake fluid*~~

ISO 4038, *Road vehicles – Hydraulic braking systems – Simple flare pipes, tapped holes, male fittings and hose end fittings*

ISO 4080, *Rubber and plastics hoses and hose assemblies – Determination of permeability to gas*

ISO 4675, *Rubber- or plastics-coated fabrics – Low-temperature bend test*

ISO 5053-1, *Industrial trucks – Vocabulary – Part 1: Types of industrial trucks*

ISO 7010, *Graphical symbols – Safety colours and safety signs – Registered safety signs*

~~ISO 7866:2012, *Gas cylinders – Refillable seamless aluminum alloy gas cylinders – Design, construction and testing*~~

~~ISO 9809-1, *Gas cylinders – Refillable seamless steel gas cylinders – Design, construction and testing – Part 1: Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa*~~

ISO 10380, *Pipework – Corrugated metal hoses and hose assemblies*

ISO 10442, *Petroleum, chemical and gas service industries – Packaged, integrally geared centrifugal air compressors*

ISO 10806, *Pipework – Fittings for corrugated metal hoses*

ISO 11114-4, *Transportable gas cylinders – Compatibility of cylinder and valve materials with gas contents – Part 4: Test methods for selecting metallic materials resistant to hydrogen embrittlement*

ISO 12100, *Safety of machinery – General principles for design – Risk assessment and risk reduction*

ISO 13226, *Rubber – Standard reference elastomers (SREs) for characterizing the effect of liquids on vulcanized rubbers*

ISO 13849-1, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

ISO 13849-2, *Safety of machinery – Safety-related parts of control systems – Part 2: Validation*

ISO 14113, *Gas welding equipment – Rubber and plastics hose and hose assemblies for use with industrial gases up to 450 bar (45 MPa)*

~~ISO/TS 14687-2, *Hydrogen fuel – Product specification – Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles*~~

~~ISO 15500-12, *Road vehicles – Compressed natural gas (CNG) fuel system components – Part 12: Pressure relief valve (PRV)*~~

ISO 15649, *Petroleum and natural gas industries – Piping*

~~ISO/TS 15869:2009, *Gaseous hydrogen and hydrogen blends – Land vehicle fuel tanks*~~

ISO/TR 15916, *Basic considerations for the safety of hydrogen systems*

ISO 16010, *Elastomeric seals – Material requirements for seals used in pipes and fittings carrying gaseous fuels and hydrocarbon fluids*

ISO 16111:~~2008~~2018, *Transportable gas storage devices – Hydrogen absorbed in reversible metal hydride*

ISO 17268, ~~*Compressed*~~ *Gaseous hydrogen* ~~*surface*~~ *land vehicle refuelling connection devices*

ISO 19881, *Gaseous hydrogen – Land vehicle fuel containers*

ISO 19882, *Gaseous hydrogen – Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers*

ISO 20898, *Industrial trucks – Electrical requirements*

ISO 21927-3, *Smoke and heat control systems – Part 3: Specifications for powered smoke and heat exhaust ventilators*

ISO 23551-1, *Safety and control devices for gas burners and gas-burning appliances – Particular requirements – Part 1: Automatic and semi-automatic valves*

UN GTR No. 13, *Global Technical Regulation concerning the hydrogen and fuel cell vehicles*

UN Regulation No. 134, *Uniform provisions concerning the approval of motor vehicles and their components with regard to the safety- related performance of hydrogen-fuelled vehicles (HFCV)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-485 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
abnormal operation
operation of the fuel cell power system with any one mechanical, electrical or control component malfunction or failure, in any failure mode regarded as reasonably probable in the failure mode and effects analysis (FMEA) but excluding accidental rupture or breakdown of the containers of flammable liquids, ~~vapours~~ and/or gases

3.2
equipotential bonding
permanent joining of ~~metallic~~ conductive parts to form a positive electrically conductive path that provides electrical continuity between non-current carrying ~~metal~~ conductive parts and is capable of conducting any fault current that ~~may~~ can occur

Note 1 to entry: This applies to bonding within the fuel cell ~~power~~ system and between the fuel cell ~~power~~ system and truck and does not refer to the means to ~~ground~~ earth the truck itself, such as with ~~a grounding~~ an earthing strap or with tires. ~~Acceptable methods of bonding shall be by any positive means, such as by a clamp, rivet, bolt, screw, welded joint, soldered or brazed joint, or a bonding jumper with a closed loop connector secured by a screw.~~

3.3
check-valve
fluid control device that allows fluids to flow in only one direction

3.4
~~circuit,~~ limited power circuit
circuit involving a potential greater than 42,4 V peak (30 V RMS) or 60 V DC and whose power after 60 s of operation complies with the values outlined in Table 2B and Table 2C of IEC 60950-1:2005 and IEC 60950-1:2005/AMD2:2013

Note 1 to entry: A circuit that is low voltage under both normal and single fault conditions is referred to in IEC 60950-1 as a safety extra low voltage (SELV).

3.5
low-voltage circuit
circuit involving a peak open-circuit potential of not more than 42,4 V (30 V RMS) or 60 V DC supplied by a battery, a fuel cell, a transformer having a ~~maximum volt-ampere (VA),~~ rated power output rating of less than 100 VA and a maximum secondary output of 30 V AC or by a

combination of a transformer and a fixed impedance that, as a system, complies with IEC 61558-1

Note 1 to entry: A circuit derived by connecting a resistance in series with a voltage supply circuit as a means of limiting the voltage and current is not considered to be a low-voltage circuit.

3.6
dilution boundary
extent of a flammable area or zone created by a limited release of flammable gas ~~or vapour~~, internal to the fuel cell power system or truck in which it is mounted, and controlled by mechanical ventilation or other effective means

Note 1 to entry: This is outlined in IEC 60079-10-1.

3.7
electrostatic discharge
ESD
~~discharge created by static electricity~~
transfer of electric charge between bodies of different electrostatic potentials in proximity or through direct contact

[SOURCE: IEC 60050-561:2014, 561-03-06]

3.8
fuel cell power system
generator system that uses one or more fuel cell modules to generate electric power and heat

Note 1 to entry: See Figure 1 for a block diagram of a fuel cell power system. ~~A fuel cell power system may contain all or some of the components shown in Figure 1.~~ The fuel cell power system for use with industrial trucks will be in one of the forms as outlined in 3.9 and 3.10.

[SOURCE: ~~IEC TS 62282-1:2013, 3.49, modified – Addition of second sentence to the Note to entry~~ IEC 60050-485:2020, 485-09-01, modified – addition of the Note to entry.]

3.9
self-contained system
complete system incorporated into its own housing that is intended to replace or combine with a battery system to power an industrial truck

Note 1 to entry: Display and control functions ~~may~~ can be located outside the system's housing in proximity to the operator's compartment. However, if counterweight is required outside the system's housing or direct communication is required between the system and the truck controller, then it will be considered an integrated system (see 3.10).

3.10
integrated fuel cell power system
complete system of fuel cell components and parts that are incorporated into the industrial truck with the various parts of the system potentially distributed throughout the truck

3.11
hazardous ~~(classified) areas~~ zone
any work area or space where combustible dust, ignitable fibres, or flammable, volatile liquids, gases, ~~vapours~~ or mixtures are or ~~may~~ can be present in the air in quantities sufficient to produce explosive or ignitable mixtures as defined by IEC 60079-10-1

3.12
integral
something that is either contained within the fuel cell power system or is external to it, but is a part of the fuel cell power system

3.13
lower flammability limit
LFL
minimum concentration of fuel in a fuel-air mixture where a combustion can be ignited by an ignition source

Note 1 to entry: A fuel-air mixture is flammable when combustion can be started by an ignition source. The main component concerns the proportions or composition of the fuel-air mixture. A mixture that has less than a critical amount of fuel, known as the lower flammability limit (LFL) or more than a critical amount of fuel, known as the rich or upper flammability limit (UFL), will not be flammable.

3.14
maximum allowable working pressure
MAWP
maximum gauge pressure at which a fuel cell or fuel cell power system ~~may~~ can be operated

Note 1 to entry: See Annex A for a comparison table of pressure terms.

Note 2 to entry: The maximum allowable working pressure is expressed in Pa.

Note 3 to entry: The maximum allowable working pressure is the pressure used in determining the setting of pressure limiting/relieving devices installed to protect a component or system from accidental over-pressuring.

[SOURCE: ~~IEC TS 62282-1:2013, 3.86.3, modified – Addition of new Note 1 to entry~~ IEC 60050-485:2020, 485-17-03, modified – addition of new Note 1 to entry.]

~~**3.15**~~
~~**maximum continuous load rating**~~
~~maximum continuous power that can be sustained by the fuel cell power system independent of any electrical energy storage device or storage component at 25 °C and ambient pressure 0,1 MPa~~

3.15
maximum operating pressure
MOP
highest gauge pressure of a component or the system that is expected during normal operation

Note 1 to entry: See Annex A for a comparison table of pressure terms.

3.16
normal release
limited ~~internal~~ localized volumes of ~~flammable vapour~~ hydrogen concentrations released during normal operation that ~~may~~ can include fuel cell purge

3.17
normal operation
all operating and non-operating modes encountered during product use that are not the result of a malfunction or failure

3.18
pressure relief device
PRD
pressure and/or temperature activated device used to prevent the pressure from rising above a predetermined maximum and thereby prevent failure of a pressurized part or system

3.19
thermally activated pressure relief device
TPRD
pressure relief device (3.18) activated ~~thermally~~ by temperature

3.20
risk assessment
overall process comprising a risk analysis and a risk evaluation

3.21
risk analysis
systemic use of available information to identify hazards and to estimate the risk

3.22
risk evaluation
procedure based on the risk analysis to determine whether a tolerable risk has been achieved

3.23
safety control
automatic controls and interlocks including relays, switches, sensors and other auxiliary equipment used in conjunction therewith to form a safety control system, which is intended to prevent unsafe operation of the controlled equipment

3.24
safety critical component
component, device, circuit, software or similar part whose failure would affect the safety of the fuel cell power system as determined in 4.16

3.25
service pressure
nominal working pressure
pressure, as specified by the manufacturer, at a uniform gas temperature of 15 °C and with full gas content

Note 1 to entry: This term only relates to the hydrogen pressure vessel.

Note 2 to entry: See Annex A for a comparison table of pressure terms.

~~**3.24**~~
~~**gas purge**~~
~~protective operation to remove gases and/or liquids, such as fuel, hydrogen, air or water, from a fuel cell power system~~

~~[SOURCE: IEC TS 62282-1:2013, 3.60]~~

~~**3.25**~~
~~**touch current**~~
~~electric current through a human body or an animal body when it touches one or more accessible parts~~

3.26
zone system of classification
means for classifying areas within the fuel cell power system using the methods outlined in IEC 60079-10-1

~~Note 1 to entry: The potential zones of this system are as follows:~~

~~**Group II, zone 0** – A location in which ignitable concentrations of flammable gases or vapours are present for long periods of time (e.g. inside the fuel cell stack or other hydrogen carrying components).~~

~~**Group II, zone 1** – A location:~~

~~a) in which ignitable concentrations of flammable gases or vapours are likely to exist under normal operating conditions; or~~

~~b) in which ignitable concentrations of flammable gases or vapours may exist frequently because of repair or maintenance operations or because of leakage; or~~

c) in which equipment is operated or processes are carried on of such a nature that equipment breakdown or fault operations could result in the release of ignitable concentrations of flammable gases or vapours and also cause simultaneous failure of electrical equipment in a mode to cause the electrical equipment to become a source of ignition; or

d) that is adjacent to a Group II, zone 0 location from which ignitable concentrations of vapours could be communicated, unless communication is prevented by adequate positive pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided (e.g. space in which purge gases are immediately released to be diluted or areas immediately adjacent to the fuel cell stack and hydrogen recirculation system).

Group II, zone 2 – A location:

a) in which ignitable concentrations of flammable gases or vapours are not likely to occur in normal operation and if they do occur, will exist only for a short period; or

b) in which volatile flammable liquids, flammable gases or flammable vapours are handled, processed, or used, but in which the liquids, gases or vapours normally are confined within closed containers of closed systems from which then can escape only as a result of accidental rupture or breakdown of the containers or system or as a result of abnormal operation of the equipment with which the liquids or gases are handled, processed, or used; or

c) in which ignitable concentrations of flammable gases or vapours normally are prevented by positive mechanical ventilation, but which may become hazardous as result of failure or abnormal operation of the ventilation equipment; or

d) that is adjacent to a group II, zone 1 location from which ignitable concentrations of flammable gases or vapours could be communicated, unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided (e.g. an area with a hydrogen fuel line and fittings at bulkhead locations but without components – a pass through).

Unclassified zone – A location:

a) in an area where there is no risk of ignitable concentrations of flammable gases; or

b) where flammable gases are not present as part of the standard processes; or

c) where there are no fittings that may leak; or

d) that is adjacent only to other unclassified zones or zone 2 locations (e.g. a compartment with a fuel line passing through without bulkhead connections or other fittings adjacent only to zone 2 locations and areas outside of the systems).

4 Construction requirements for safety

4.1 General

Any component of a product covered by this document shall comply with the requirements for that component. Normative references for standards covering components used in the products covered by this document are given in Clause 2.

A component is not required to comply with a specific requirement of the normatively referenced standards that:

– involves a feature or characteristic not required in the application of the component in the product covered by this document,

– is superseded by a requirement in this document, or

– is separately investigated when forming part of another component, provided the component is used within its established ratings and limitations.

Any component shall be used in accordance with its rating established for the intended conditions of use.

Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

A component that is also intended to perform other functions such as overcurrent protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any

combination thereof, shall additionally comply with the requirements of the applicable standard that covers devices that provide those functions.

4.2 Hydrogen and other fluid containing parts

4.2.1 General

Pressure or fluid containing parts shall be resistant to the action of the fluid.

~~The refuelling interface for hydrogen system shall be in accordance with ISO 17268.~~

Metallic parts containing hydrogen gas shall be resistant to hydrogen embrittlement as outlined in ISO/TR 15916. If employing a material other than as outlined in ISO/TR 15916, an evaluation for susceptibility to hydrogen embrittlement will need to be conducted in accordance with ISO 11114-4 or ISO 2626.

Where atmospheric corrosion of a part containing fluid interferes with its intended function, or permits external leakage of a fluid creating a hazardous condition, the part shall be made of corrosion-resistant material or is to be provided with a corrosion-resistant protective coating.

Any elastomeric parts, relied upon for safety such as a seal for fluids other than hydrogen, which could create a hazard when leaked (for example, a gasket between electrical and wetted parts), shall be suitable for the application as determined by ISO 1419, ISO 1421, ISO 13226, ISO 16010 and ISO 4675, as applicable.

Any elastomeric parts employed as a seal for hydrogen shall be suitable for use with hydrogen. The elastomeric materials outlined in ISO/TR 15916 shall be considered for reference and guidance. The material shall be evaluated for tensile strength and elongation as-received and after oven-ageing (based on service temperatures) in accordance with 5.20.

4.2.2 Piping, hoses, tubing and fittings

1) Where conveying gases ~~or vapours~~ at gauge pressures exceeding 103,4 kPa, liquids at pressures exceeding 1 103 kPa, or temperatures exceeding 120 °C, piping and associated component parts shall be designed, fabricated and tested to conform to all applicable specifications of ISO 15649.
2) Piping utilized at levels below the pressures and/or temperatures noted in 1) and nonmetallic piping shall be evaluated to the requirements of this document with consideration given to materials and fluids contained and service conditions, including pressures and temperatures. Non-metallic piping containing gaseous hydrogen or methanol fuel shall be designed, fabricated and tested to the additional requirements in 6).
3) Non-metallic hoses used for gaseous hydrogen or methanol fuels located outside the fuel cell power system and subject to physical stress shall meet the hydrostatic testing, adhesion (rubber only), flexibility, low-temperature flexibility, ozone resistance (for hoses with an outer protective cover of rubber), UV resistance (for hoses with plastic cover), permeability to gas, electrical conductivity, and end fitting integrity tests of ISO 14113. Materials shall be suitable for service with hydrogen fuel, or the fluid contained (i.e. methanol), in accordance with 4.2.1. Flexible hoses longer than 1,5 m shall have a stainless-steel wire braid reinforcement.
4) Flexible metal connectors and associated fittings, when used for conveying gaseous hydrogen, shall comply with ISO 10806 and ISO 10380, as required.
5) A hydrogen fuel line shall be supported to minimize chafing and to maintain at least a 51 mm clearance from exhaust- and electrical-system parts.
    a) Electrical equipment and sensors in limited power circuits that do not have enough electrical energy to damage a fuel line are not required to comply with this requirement.
    b) If it can be demonstrated that the fuel lines and wiring are sufficiently supported to prevent the clearance from being reduced to less than 12,7 mm, the clearance between fuel lines and electrical-system parts can be reduced.

6) Non-metallic hydrogen and methanol fuel lines shall:
   - be protected within ventilated enclosures where they will be subject to a minimum of mechanical or physical stresses;
   - be conductive to avoid static discharge. Compliance is determined by the continuity test of 5.10 2) for metal fuel lines, and of 5.10 3), for nonmetallic fuel lines;
   - employ materials that have been evaluated and found suitable for the fluids they contain with consideration given to temperatures they are exposed to during service. Compliance shall be determined by 5.20 and 5.21, as applicable; and
   - comply with the ESD requirements for ~~ISO 3996 or~~ ISO 4038 when connected between the fuel system and the stack.
7) Pipe, tubing, fittings, and other piping components shall be capable of withstanding a minimum hydrostatic test of 1,5 times the rated service pressure without structural failure. ~~Exception:~~ High-pressure pipe, tubing, fittings, and other piping components shall have a safety margin equivalent to the storage cylinder in use. See 4.2.3.

4.2.3 Hydrogen pressure vessels

1) Pressure vessels shall be specifically designed for the service conditions of the industrial truck application that include the maximum number of fill cycles expected, the ranges of pressures and temperatures expected during operation and filling, the effect of hydrogen on fatigue life and the frequency of inspection.
2) With reference to 1), a pressure vessel shall be designed, manufactured, and tested with the following conditions and limitations:
   a) container Category C defined in ISO 19881 shall apply;
   b) for Type 1 vessels, the vessel shall be designed and tested in accordance with ISO 19881;
   c) the term "working pressure" of the vessel as defined in ISO 19881 is identical to "service pressure" in this document;
   d) for Type 3 and Type 4 vessels, the vessel shall be designed and tested in accordance with ISO 19881, UN GTR No.13 and UN Regulation No. 134;
   e) the vessel shall be designed for the excepted life of the fuel cell power system and not fewer than 11 250 full fill cycles.

   NOTE "11 250 full fill cycles", for example, 3 refills/day, 365 days/years, 10 years = 10 950 cycles.

~~a) For Type 1 steel tanks, it shall be designed in accordance with ISO 9809-1.~~

~~b) The term "working pressure" of the container as defined in ISO/TS 15869 is identical to "service pressure" in this standard and shall be either 25 MPa, 35 MPa or 70 MPa gauge only.~~

~~c) The cylinder shall be designed for not less than 11 250 full fill cycles, which represents a 10-year life. ISO/TS 15869:2009, 4.5, 11 k) and 11 l), and Annex A do not apply.~~

~~NOTE 11 250 full fill cycles, i.e. 3 refills/day, 365 days/years, 10 years = 10 950 cycles.~~

~~d) ISO/TS 15869:2009, 9.5, and Annex E, covering alternate type tests, shall not apply.~~

~~e) ISO/TS 15869:2009, 9.2.2, shall not apply. However, stainless steels; SUS316L, AISI316L, and AISI316; having >12 % nickel composition and <0,1 % magnetic phases by volume are exempt from hydrogen compatibility tests in Clause B.2 of ISO/TS 15869:2009. The fabrication process using these materials shall not include welds.~~

~~f) In 9.2.3 of ISO/TS 15869:2009 the exemption for aluminum alloys that conform to 6.1 and 6.2 of ISO 7866:2012, shall not apply. However, aluminum alloys: A6061-T6, A6061-T62, A6061-T651 and A6061-T6511 are exempt from hydrogen compatibility tests in Clause B.2 of ISO/TS 15869:2009. The fabrication process using these aluminum materials shall not include welds.~~

~~g) Other than indicated in d) or e), hydrogen compatibility of metallic materials in contact with hydrogen gas shall be demonstrated by fulfilling the requirements of Clause B.2, point b) or c) of ISO/TS 15869:2009 by using hydrogen that meets the requirements of ISO/TS 14687-~~

~~2 and with the additional requirements that the oxygen limit be changed to less than 1 µmol per mol and the water limit shall be changed to less than 3 µmol per mol.~~

~~h) If fatigue testing is conducted in accordance with point c) of Clause B.2 of ISO/TS 15869:2009, it shall be done using hydrogen quality as specified in f) above, and at a rate not exceeding 10 cycles per minute. The sample vessel shall be pressure cycled until failure or to a minimum of 3 times the full fill cycles specified in c) above. The sample vessel is allowed to fail by leakage and not rupture at a number of cycles greater than the number of full fill cycles specified in c) above. If the sample vessel achieves 3 times the number of full fill cycles specified in c) above without failure, the ambient temperature pressure cycling test, specified in Clause B.7 of ISO/TS 15869:2009, and the leak-before-break (LBB) test in Clause B.8 of ISO/TS 15869:2009 is not needed.~~

~~i) With regards to h) above, leakage is the escape of gas from a vessel that is not attributed to leakage at a fitting connection or to permeation, and which is not caused by rupture. Escape of gas from a crack would be considered leakage and not rupture. Rupture is a violent breach of the vessel sidewall, head or bottom.~~

~~j) Clause B.2, point a) of ISO/TS 15869:2009 shall not apply.~~

3) A pressure vessel and fill fitting shall be placed within the plan view outline of the industrial truck or placed in an enclosure as defined in 4.13 and located to minimize the possibility of damage to the vessel or hydrogen-related fittings.

4) An excess-flow and check-valve, if present, shall be directly connected to the pressure vessel or mounted in line with the pressure vessel, where there is no shut-off device in between the pressure vessel and the check valve, so as to minimize the negative effects of shock, vibration and accidental damage.

5) The refuelling line shall be fitted with a redundant check valve for the check valve in the receptacle specified in ISO 17268.

6) Pressure vessels shall have a provision for being de-fuelled (de-pressurized) and purged of hydrogen using an inert gas as outlined in the operating instructions or the maintenance manual, as applicable, provided with the fuel cell power system.

7) A manual valve to isolate the fuel supply shall be located near the pressure vessel so that the fuel supply to the fuel power system can be shut off for maintenance or long-term storage.

8) The hydrogen pressure vessel shall be permanently mounted to the fuel cell power system module or to the industrial truck to ensure the pressure vessel does not become dislodged while in use and is not removable for refuelling.

4.2.4 Metal hydride container

Fuel storage systems using hydrogen stored in metal hydrides shall comply with Clause 4, Clause 5, and Clause 6 of ISO 16111:~~2008~~2018.

4.2.5 Methanol fuel tank

1) Methanol fuel ~~tanks~~ vessels shall be constructed of suitable materials in accordance with 4.2.1 and 4.2.2 and shall meet the requirements as noted below. Such vessels, and their related joints and fittings, shall be designed and constructed with adequate strength for functionality and leakage resistance to prevent unintended releases.

2) Methanol fuel ~~tanks~~ vessels shall be specifically designed for the service conditions of the industrial truck application that includes the ranges of pressures and temperatures expected during operation and filling, the effect of methanol on fatigue life of the tank, and the frequency of inspection.

3) A manual valve to isolate the fuel supply shall be located near the fuel tank so that the fuel supply to the fuel cell power system can be shut off for maintenance or long term storage.

4) A methanol fuel ~~tank~~ vessel and fill fitting shall be placed within the truck envelope or placed in an enclosure as defined in 4.13, and located to minimize the possibility of damage to the ~~tank~~ vessel or fittings.

5) The methanol fuel tank shall be permanently mounted to the fuel cell power system module or to the industrial truck to ensure the tank does not become dislodged while in use and is not removable for refuelling.

4.3 Refueling

The refueling interface shall correspond to the container pressure rating (see 4.2.3 2)c)) and shall be in accordance with ISO 17268.

4.4 Over-pressure and thermal protection

1) The hydrogen pressure vessel shall be protected from the effects of fire by a nonreclosing thermally activated pressure relief device (TPRD) that is designed, manufactured and tested in accordance with ~~ISO 15500-12~~ ISO 19882.
2) Components and piping located downstream of a pressure reducing valve that are rated to a pressure that is lower than the maximum inlet pressure of the pressure reducing valve shall be protected from over-pressure in the event of a failure of the pressure reducing valve by way of a pressure relief ~~valve or pressure relief~~ device.
3) Pressure relief devices shall be suitable for their application, including materials in contact with hydrogen and pressure and flow ratings.
4) Pressure relief devices operating at over 1 000 kPa shall be sized and designed to limit the pressure during a fault to less than 110 % of the maximum allowable working pressure. Re-closure shall occur at no less than 90 % of the set point. Pressure relief devices operating at or below 1 000 kPa shall be sized and designed to limit the pressure during a fault to less than 125 % of the maximum allowable working pressure. Re-closure shall occur at no less than 90 % of the set point. Fuel cell stack shall be protected in accordance with IEC 62282-2-100.
5) When provided, pressure relief discharge piping shall be sized to ensure compliance with 4.4 4).
6) A pressure relief ~~valve~~ device shall have its discharge located so that operation of the named device does not result in a hazardous situation such as:
   a) hydrogen gas in excess of 25 % of the lower flammability limit (LFL) escaping to an unclassified or pressure-confined area within the fuel cell power system. The discharge of the pressure relief ~~valve~~ device can be located within the fuel cell power system by using an adequate ventilation or implementing an adequate safety-controlled system composed of a hydrogen sensor and a hydrogen shut-off valve plugging the leak in case of detection;
   b) deposition of moisture on live parts that could create a risk of electric shock;
   c) possible access of foreign objects, moisture or debris to enter the venting system not protected by caps, covers or other means;
   d) chance for the venting system to become unsecured or removed such that it would affect the intended flow path, or
   e) the pressure release being directed towards or impinged towards the normal operator position.
7) A pressure relief device vent shall be secured at intervals in such a manner as to minimize the possibility of damage, corrosion, or breakage of either the vent line or the pressure relief device due to expansion, contraction, vibration, strains, or wear and to preclude any loosening while in operation.
8) The vent system including the outlet connection of the relief device and associated vent lines shall be designed to withstand the maximum pressure developed during full flow operation of the relief device without becoming detached from its securement ~~and without the vent cap, if provided, from being expelled~~. If provided, the vent cap shall be secured for the safety.

~~All components located downstream from the pressure regulating valve and which are connected to the relief device, as shown in the example given by Figures 2, 3 and 4, shall have~~

~~a) a pressure rating not less than 110 % of the maximum downstream pressure of the regulating valve on systems having pressure ratings greater than 1 000 kPa, and~~

~~b) a pressure rating not less than 125 % of the maximum downstream pressure of the regulating valve on systems having pressure ratings less than 1 000 kPa in accordance with 4.3.4.~~

9) Pressure relief devices, as shown in the examples in Figure 2, Figure 3, and Figure 4, shall be in accordance with ISO 15649.

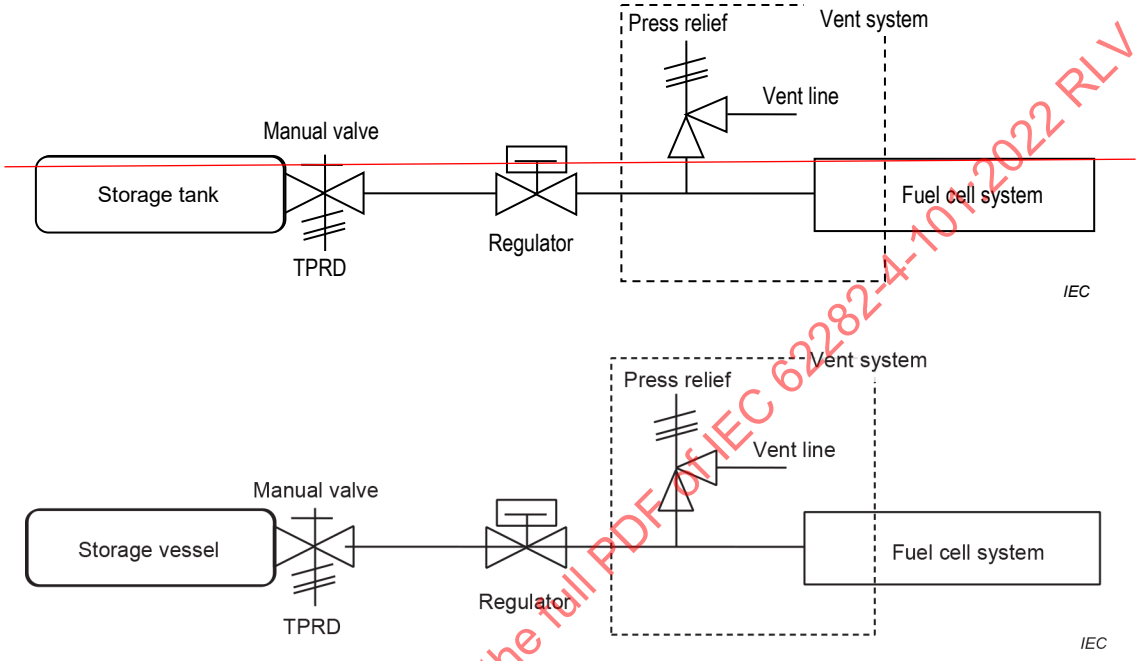


Figure 2 – Example of a diagram with vent system covering components downstream of the regulator

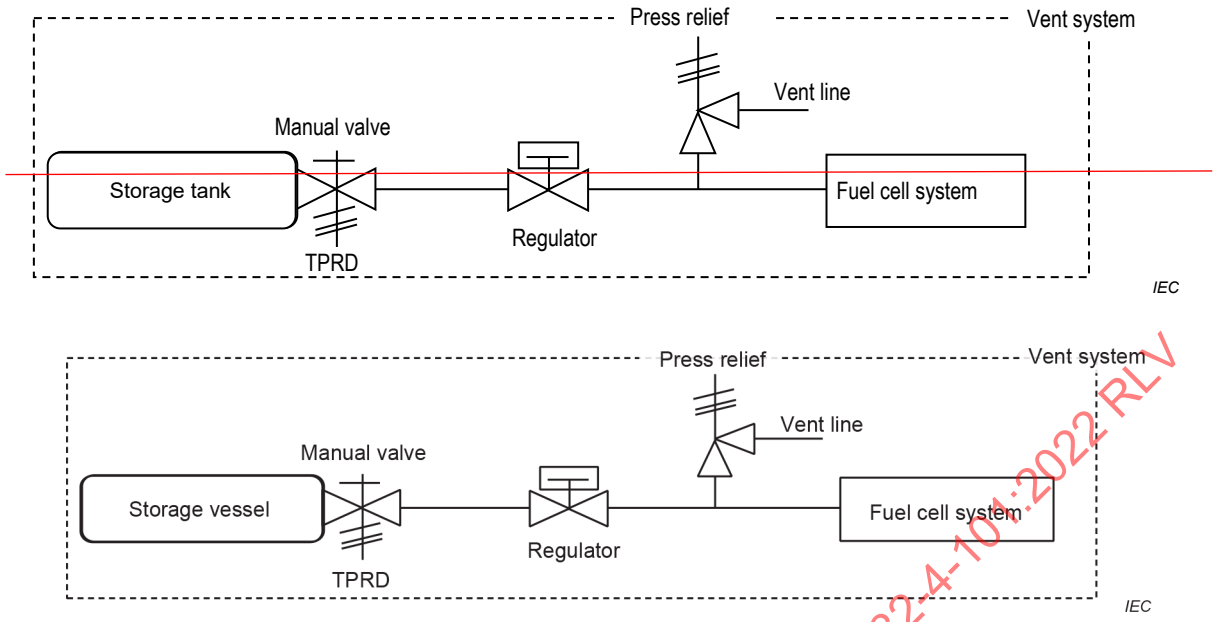


Figure 3 – Example of a diagram with vent system covering all components

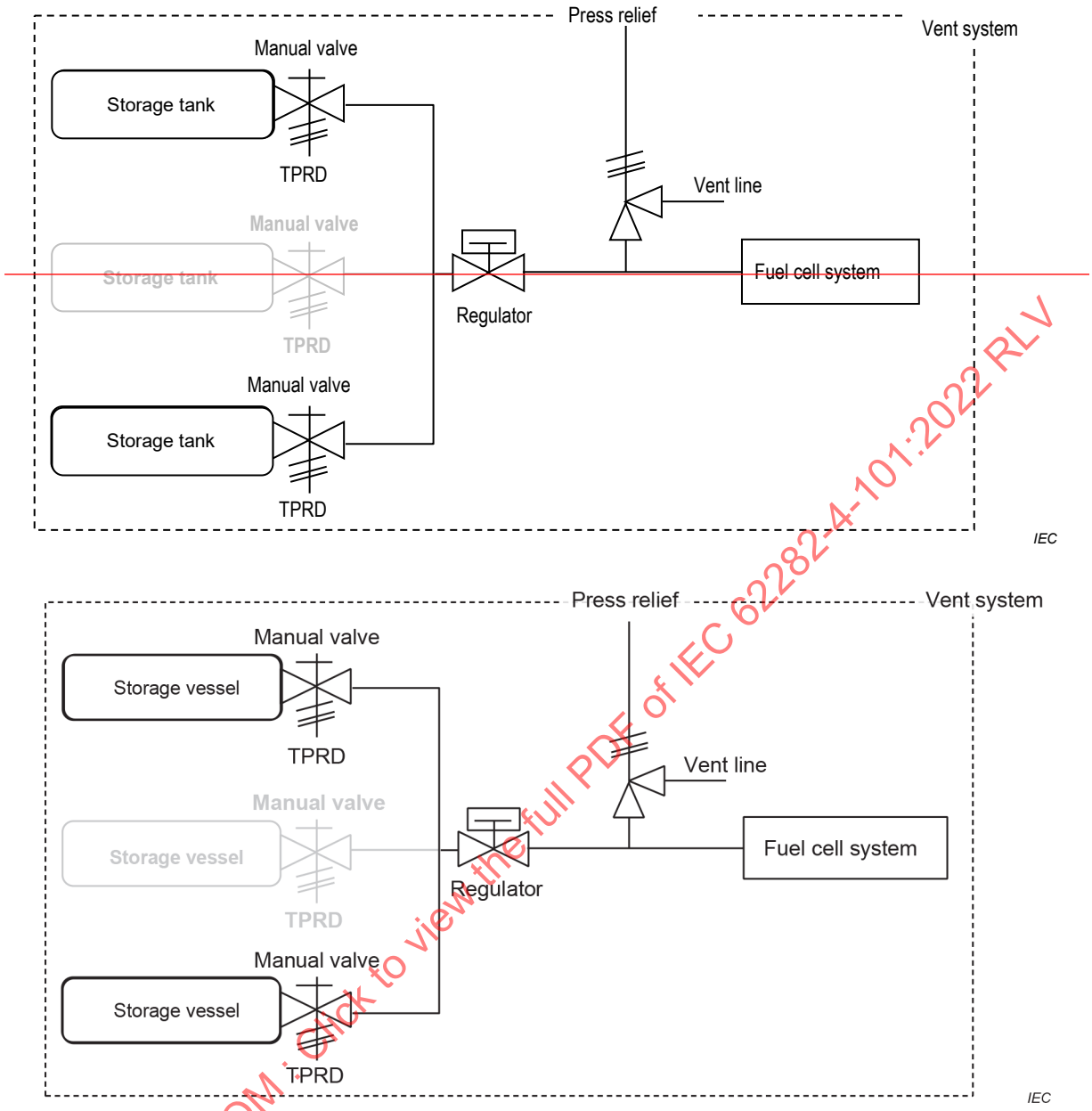


Figure 4 – Example of a diagram with vent system covering all components in a multiple storage ~~tank~~ vessel system

4.5 Regulators

The gas pressure regulator shall be equipped with a vent limiter or a vent line.

4.6 Operating and shut-off valves

1) Valves shall be rated for the application, including pressure, temperature, fluids contacted, and electrical ratings, if applicable.
   a) Electrically operated valves shall comply with ~~IEC 60730-2-17~~ ISO 23551-1.
   b) Valves for high pressure piping shall be tested in accordance with ISO 15649, instead of the external leakage test and the hydrostatic strength test of ISO 23551-1.
   c) Valves for flammable fluids shall comply with ISO 23551-1.
2) Fuels supplied to the fuel cell power system shall be supplied through fuel lines provided with at least one automatic safety shut-off valve. The safety shut-off valve ~~may~~ can also be an operating valve. The closing time for a safety shut-off valve shall be no greater than 5 s.

3) If an emergency manual shut-off valve is deemed necessary according to 4.16, it shall be in a readily accessible location and shall not have more than 90° rotation from the open to the closed positions. Any key or tool shall not prevent access to the manual shutoff valve ~~shall not require the use of any key or tool~~. The valve shall be securely mounted and shielded or installed in a protected location to minimize damage from vibration or collision.

4) Where a manual valve is used, the valve shall be indicated with a marking in accordance with Clause 7 3)f).

5) Electrical and other automatically operated safety shut-off valves shall fail in a safe position.

6) Electrical valves located in classified areas shall be rated for the area of classification.

4.7 Filters

Air and fluid filters shall be suitable for the application and readily accessible if required to be inspected, cleaned, or replaced.

4.8 Pumps and compressors

1) Air compressors and air vacuum pumps employed in the system shall comply with ISO 10442.

2) Water pumps shall comply with IEC 60335-2-41.

3) Chemical and gaseous hydrogen pumps and compressors shall be evaluated to the applicable material compatibility requirements, mechanical and electrical requirements of this document.

4) A flammable fluid compressor or pump with rotating or other type dynamic seals, shall be provided with adequate ventilation so that small releases of hydrogen ~~or other flammable vapour~~ under normal operating conditions shall not allow the concentration of ~~flammable vapours~~ hydrogen to be above 25 % of the lower flammability limit (LFL) in the unclassified areas of the fuel cell power system during normal release.

4.9 Electrically operated pressure sensing and controlling devices

1) Pressure activated switches and transducers shall be rated for the application. A pressure regulating control for a flammable or combustible fluid shall be suitable for its classification and the fluid it contains.

2) The maximum operating pressure of a pressure limiting or regulating control shall not exceed 90 % of the operating pressure of a pressure relief ~~valve~~ device. An accessible and adjustable pressure regulating control that can exceed the limits of the system shall be reliably sealed at the maximum operating pressure at which it is intended to operate.

4.10 Ventilation to prevent the build up of flammable gases ~~and vapours~~

1) A fuel cell power system shall be provided with adequate ventilation so that normal releases under normal operating conditions shall not allow the concentration of ~~flammable vapours~~ hydrogen to be above 25 % of the lower flammability limit (LFL) in the unclassified zones of the fuel cell power system. This normal release shall include nominal stack fuel leakage rates or fuel purges that ~~may~~ can occur during operation.

2) The diluted concentrations of ~~flammable vapours~~ hydrogen exiting the fuel cell power system even during abnormal operation shall not exceed 25 % of the lower flammability limit (LFL).

NOTE See IEC 62282-3-100 or IEC 62282-5-100.

3) The extent of a flammable region at a source of limited release (dilution boundary) shall be determined through appropriate analysis as outlined in IEC 60079-10-1.

4) Equipment located within the dilution boundary shall be suitable for the classification. Reference ~~may~~ can be made to IEC 60079-0.

5) Abnormal releases of flammable fluids shall not create a safety hazard in accordance with 4.16, and shall result in the appropriate action, including the prompt shut down of the equipment, if necessary, that will mitigate the hazard or prevent the creation of additional hazards.

6) Mechanical ventilation shall be provided to keep the dilution boundary of 25 % lower flammability limit (LFL), under conditions of normal release, away from the unclassified components. Failure of ventilation shall cause the fuel cell power system to respond in such a way that shall mitigate any hazard or prevent the creation of additional hazards in accordance with 4.16. This ~~may~~ can include shutting off, either through the detection of high gas~~/vapour~~ concentration or with ventilation interlock provisions.

   a) ~~Exception No. 1:~~ Limited, localized volumes of ~~flammable vapour~~ hydrogen concentration within the fuel cell power system ~~may~~ can momentarily exceed the 25 % LFL of the ~~flammable vapour~~ hydrogen, but it shall be determined, in accordance with 4.16, that this transient condition does not create a safety hazard.

   b) ~~Exception No. 2:~~ Mechanical ventilation is not required if it can be determined that the flammable gas~~/vapour~~ concentration level falls below 25 % LFL under any conditions of normal release.

7) If gas detection is employed as a critical safety component in the fuel cell power system, the gas detection system shall comply with IEC 60079-29-1 and IEC 60079-29-4. Gas detection systems shall be located where they can most effectively measure the accumulation of ~~vapour~~ hydrogen within the fuel cell power system and monitor the ventilation output as determined necessary.

8) If gas detection is employed as a critical safety component in the fuel cell power system, it shall be located in a control circuit that complies with IEC 60730-1:2013, IEC 60730-1:2013/AMD1:2015 and IEC 60730-1:2013/AMD2:2020, Annex H, and in accordance with 4.15.1 of this document.

9) In case of hydrogen leakage, the shut down valve shall be automatically operated. Similarly, the electrical switch shall be automatically shut down. The safety hydrogen sensor shall remain operational provided this does not increase the risk. In case of hydrogen safety sensor failure, the shut down valve shall be automatically operated. Similarly, the electrical switch shall be automatically shut down. Considering battery and tank safety testing, the appropriate documents such as IEC 62619 should be applied.

10) Ventilation openings and ducts shall not become obstructed or compromised when the fuel cell power system is normally operated in the truck.

11) Fans, blowers, and other devices employed for the ventilation system shall be suitable for the application. If fans and ventilators are used as the primary safety mechanism to prevent the build-up of flammable gas~~/vapour~~, the failure of the ventilation system shall not create a safety hazard in accordance with 4.16. Fans shall comply with IEC 60335-2-80. Ventilators shall comply with ISO 21927-3.

4.11 Electrostatic discharge (ESD)

1) Hydrogen fuel containing parts and parts within classified zones (see 3.26) of the equipment shall be constructed of materials that do not promote static discharges.

2) The exposed portion of moving metal parts such as fan blades and wheels, located in classified areas of the system shall be made of, or covered with, medium brass, bronze, copper or aluminum with hardness not more than Rockwell B66. Energy storage components such as batteries or ultracapacitors, and major power electronics components, such as fuel cell stack module, shall have their external conductive cases equipotentially bonded.

3) Components with non-current carrying metal parts and cases located in classified zones within the equipment shall be equipotentially bonded.

4) When a self-contained fuel cell power system is installed in a truck, a conductive path shall be provided between the fuel cell equipment components requiring equipotential bonding and ~~the grounding means of~~ the chassis of the truck.

5) Any fuel receptacle on the fuel cell power system provided for refuelling shall be equipotentially bonded to the ~~truck~~ fuel cell power system chassis.

~~The fuel cell power system installation instructions shall indicate that a means shall be provided in the end installation so that there is a conductive path between the truck body and ground. The installation instructions shall indicate that the total resistance between the fuel cell power system and ground shall not exceed 25 MΩ and any fuel receptacle on the fuel cell power system provided for refuelling shall be bonded to the truck chassis.~~

~~Nonmetallic fluid containing parts such as hoses and nonmetallic moving parts such as fan blades and belts located within the dilution boundary (see 3.6 and 4.9.3), shall comply with 3) of 5.10 or the test in accordance with the exception to 3) of 5.10.~~

6) Markings and instructions regarding the hazard involved with the buildup of static discharge and the means to mitigate this hazard shall be in accordance with Clause 7 3)d) and 8.4 2).

4.12 Discharges including methanol emissions and waste materials

1) The fuel cell power system shall be constructed so that waste materials, including water, are not exhausted, discharged or leaked in a manner that could create unsafe conditions.

2) Emissions from methanol fueled fuel cell power systems shall not exceed safe limits. Compliance is determined by the emission of effluents test of 5.16. Systems shall be designed to prevent emissions from entering the passenger compartment of the end use industrial truck application.

4.13 Enclosures

1) A fuel cell power system shall be enclosed for protection from access by persons to electrical parts, safety circuits, hazardous moving parts, hot surfaces, and other parts that ~~may~~ can be a risk of injury.

2) Openings in a fuel cell power system enclosure of hazardous parts shall be located and sized to provide adequate protection from access to hazardous parts complying with a minimum IPXXB or IP2X minimum rating as outlined in IEC 60529.

3) An external enclosure for a fuel cell power system provided with an IP rating ~~for ingress of water with harmful effects shall comply with 1) of 5.18.1. See also 2) of 5.18.1~~ in accordance with Clause 7 2)j) shall comply with the rain test in 5.17.1.

4) An external enclosure shall comply with the test of 5.18.1, unless the required protection is provided by the truck for an integrated fuel cell power system.

5) Non-metallic enclosure materials shall be flame rated V-1 minimum in accordance with IEC 60695-11-10 or shall comply with the test for thermoplastic materials in 5.19.

6) Any thermoplastic enclosure of a fuel cell power system shall be suitable for the range of temperatures that it is subjected to during use.

7) The system enclosure shall be ~~so~~ designed ~~that water (e.g. rain, condensate) can´t stay inside the enclosure~~ to prevent the accumulation of liquids inside the enclosure. ~~Drains should be integrated in the enclosure.~~ Drains are one potential means for compliance.

~~In case of hydrogen leakage, the shut down valve shall be automatically operated. Similarly, the electrical switch shall be automatically shut down. The safety hydrogen sensor shall remain operational provided this does not increase the risk. In case of hydrogen safety sensor failure, the shut down valve shall be automatically operated. Similarly the electrical switch shall be automatically shut down. Considering battery and tank safety testing, the appropriate standards such as: IEC 62133 should be applied.~~

4.14 ~~Fuel cell power system electrical components~~ Electrical system

4.14.1 General

1) Electrical components shall be rated for the application and conform to the appropriate document for those components. They shall be located and secured so that they are not adversely affected by vibration, temperature, environment and other effects during normal operation of the fuel cell power system.

2) If electrical equipment internal to the fuel cell power system is located in hazardous zones, it shall be identified ~~hazard. Reference could be made~~ and managed according to IEC 60079-0.

3) EMC is subject to regional requirements. See ISO/TS 3691-7 and ISO/TS 3691-8.

4.14.2 Internal wiring

1) Internal wiring shall consist of any of the following:
   a) general-use wire specified in ~~IEC 60204-1~~ IEC 60364~~, or~~;
   b) appliance-wiring material of one or more of the types specified in Table 1.
2) The wiring shall be considered with respect to the temperature and conditions of service to which the wiring is to be subjected in the end truck installation.
3) ~~Exception:~~ At the connection to a component, wiring is permitted to extend beyond the braid for a length of no more than 254 mm.
4) Appliance-wiring material having a thickness of insulation less than the minimum acceptable value specified in Table 1 is permitted for a particular application, provided the insulation is considered with respect to temperature and conditions of service and is equivalent to one of the materials specified in Table 1.
5) A bare conductor is permitted to be insulated with insulating tubing ~~or with noncarbonizable beads~~.
6) Wiring shall be protected against mechanical damage by:
   – enclosing it within the fuel cell power system enclosure for self-contained fuel cell power systems, and
   – enclosing it within the body of the truck for integrated fuel cell power systems.
7) A conductor connected to a moving or movable part that cannot be protected, shall be designed for the intended use and shall comply with the test requirements in this document. Consideration shall be given to the resistance of the conductor to damage resulting from flexing, abrasion, or impact. Flexible metallic conduit is to be used only for flexible connections subject to small and infrequent movements.
8) Wiring connections to a continuously moving part, or a part for which the degree of movement is appreciable, shall be in accordance with IEC 60227-5.
9) ~~Exception:~~ The tubing ~~may~~ can be omitted from exposed moving conductors that are readily visible to the operator and are, therefore, subject to replacement when damaged. The maintenance manual shall include instructions regarding inspection of these conductors for replacement when damage occurs in accordance with 8.2 5).
10) All of the ~~splices and~~ connections shall be mechanically secure and shall provide electrical contact without stress on connections and terminals. A ~~splice~~ connection shall be provided with insulation equivalent to that on the wires involved.
11) A hole, through which insulated conductors pass, shall be provided with a smooth, rounded bushing, or shall have smooth, rounded surfaces upon which the insulated conductors may bear.
12) Wireways shall be smooth and free from sharp edges, burrs, fins, or moving parts that ~~may~~ can damage wiring.
13) An internal-wiring connection shall be made with a solder lug or pressure terminal connector.
14) ~~Exception:~~ Control wiring and other small conductors, which are connected by crimped or soldered special-type lugs or eyelets including barrel terminals or by ultrasonic welding and that are insulated in accordance with 7), comply with the intent of this requirement.
15) A terminal lug shall be arranged so that in any position it cannot contact either the metal enclosure and non-energized accessible metal parts or other electrical circuits, or the shank of the lug shall be provided with insulation equivalent to that on the conductor.

Table 1 – Appliance-wiring material

Wire insulation	Minimum acceptable average insulation thickness mm
Rubber, neoprene or thermoplastic (PVC)	0,38 plus an impregnated braid, or 0,75 without a braid

4.14.3 External wiring

1) An external electrical output lead shall be of a size and capacity such that for a ~~continuous maximum~~ rated power output, the insulation temperature does not exceed its rating at maximum ambient temperature. It shall be provided with insulation able to withstand flexing, handling, and impact at temperatures between 50 °C and –20 °C. If intended for exposure to extreme temperatures above 50 °C and at or below –20 °C, the lead shall comply with 5.22. The average insulation thickness shall be fixed in accordance with IEC 60227-3. The length of the lead and connector assembly shall be as short as practicable without interfering with the disconnecting operation and without placing stress on terminals when installed in the truck.
2) An external electrical output connector shall be rated for the output of the fuel cell power system. Live parts shall be recessed from the face of the connector to reduce the possibility of shorting. A removable portion of the connector shall be provided with means for being grasped during removal. The connector shall be located to provide mechanical protection when the fuel cell power system is installed in the end use.
3) External wiring shall be protected against mechanical damage by
   a) enclosing it in the body of the truck,
   b) enclosing it in a metal raceway such as armored cable, rigid metal conduit or electrical metallic tubing, or
   c) protecting it with metal, phenolic composition, or other thermosetting material having equivalent mechanical strength and resistance to impact and having no greater combustibility than phenolic.
4) This enclosure or protection shall be such that any flame or molten material, which ~~may~~ can be caused by an electrical disturbance in the wiring, cannot reach surrounding combustible material.

   ~~Exception No. 1:~~ This requirement does not apply to flexible external leads that require flexibility for disconnection, output leads of the fuel cell power system for example, that comply with 1).

   ~~Exception No. 2:~~ This requirement does not apply to leads that, if damaged, do not result in a hazard.

4.14.4 Emergency switching off requirements (disconnection) for connections for fuel cell power system

1) An emergency switching off control or battery connector when used as an emergency switching off device shall be accessible to the operator in the normal operating position at all times.
2) The emergency switching off device shall be capable of interrupting without danger the power supplies to all moving elements where an interruption does not increase the potential risk. It shall be capable of interrupting the normal maximum current (including motor starting current) by one of the following methods:
   a) fuel cell connector for voltage up to and including DC 120 V DC. Above 120 V DC, provision shall be made to prevent the use of the battery connector for emergency switching off purposes;
   b) manually actuated power switch directly disconnecting one line of power supply;
   c) manually actuated control switch disconnecting the power supply to the coil of one contactor in one line of the power supply. Simultaneously the power controller (e.g.

inverter or controller for separate excited motors) shall be deactivated. In trucks driven by series-wound DC motor(s) with mechanical commutator without power controller, two independent contactors are necessary to switch off battery supply.

In the case of b) or c), they shall be a positive action type in accordance with IEC 60947-5-1 and the actuator coloured red. See also IEC 60947-3.

A contrasting colour shall be used if the background is red.

It shall be possible to re-establish the power supply to the moving elements only by manual resetting of the switching off device followed by the normal operation of the controls.

3) If the fuel cell connector is used as an emergency switching off system, the removable part of the connector shall have a means for disconnecting without damage to the fuel cell connectors or cables.

4) When the connector is used for emergency switching off, the device shall be capable of being disconnected quickly in case of emergency and the two half-connectors shall be able to be separated easily. The maximum force to separate the two half connectors shall not exceed 150 N.

4.14.5 Motors

Motors shall comply with IEC 60034, unless they are located in limited power circuits.

A motor cannot comply with this requirement if located in a low voltage circuit.

4.14.6 Switches and motor controllers

1) A motor controller or switch shall be rated for the load that it controls. A motor controller shall have the current interrupting capacity not less than the locked rotor load of the motor controlled in accordance with IEC 60204-1 and shall comply with the additional requirements for motor controls as specified in ISO 20898.

2) A switch that controls an inductive load other than a motor, such as transformer, shall not be less than twice the rated full-load current of the transformer, or similar device, unless the switch has been investigated and found acceptable for the application.

4.14.7 Transformers and power supplies

1) Transformers located in hazardous voltage circuits shall be provided with overcurrent protection.

2) Class 2 and Class 3 transformers shall comply with IEC 60950-1 or IEC 61204-7.

3) Power supplies other than Class 2 shall comply with IEC 60950-1 or IEC 61204-7, as applicable.

4.14.8 Inverters, converters and controllers

Inverters, converters and controllers shall be subjected to the abnormal condition tests (faulted components) of ~~IEC 62103~~ IEC 62477-1.

4.14.9 Lamps and lampholders

1) Lamps and lampholders shall be totally enclosed. A lamp lens shall be protected against mechanical damage by bars, grids, recessing or equivalent means.

2) A light emitting diode (LED), vacuum fluorescent display (VFD), backlit liquid crystal display (LCD), and any other display that ~~may~~ can be a source of ignition when mechanically damaged shall be protected against mechanical damage.

4.14.10 Energy storage components

4.14.10.1 Batteries

1) Secondary lithium batteries shall comply with ~~IEC 62133~~ IEC 62619 and shall be protected from reverse polarity charging. ~~Lithium cells shall be provided with the appropriate reverse charging protection in the battery circuitry.~~

2) Lead acid type batteries shall comply with IEC TS 61430.

3) Other chemistries, such as nickel-cadmium or nickel-metal-hydride cells, shall comply with IEC 62133-1.

4) For batteries employed as a fuel cell power system/power battery combination:

   a) Cells employing metal containers, such as alkaline batteries, shall be insulated from one another and from a metal tray or metal battery compartment. Insulation of wood or other material shall be:

      i) treated or painted to reduce deterioration by the battery electrolyte, and

      ii) constructed to reduce the risk of damage to the insulation during the normal operation and maintenance of the truck.

   b) ~~Battery terminals that are threaded shall be provided with lock washers or equivalent means to reduce the risk of a loose wiring nut-terminal connection causing an arc ignition of gases from the battery that may be present. A flat washer shall be used between a lock washer and any surface that is made of lead.~~

      Battery terminals shall be connected in a safe way avoiding any possibility that a conductive component could connect battery terminals generating an electric arc.

   c) Battery terminals shall be protected by insulating boots or covers, if applicable.

5) ~~Exception No. 1:~~ A terminal that is intended to be connected to ground on the truck frame ~~need not~~ can be provided with a boot or cover.

~~Exception No. 2: this requirement does not apply to a built-in battery charger equipped with a ground-fault circuit interrupter or having an isolated secondary output.~~

4.14.10.2 Double layer capacitors (ultracapacitors)

For ultracapacitors employed as a fuel cell power system/ultracapacitor combination:

1) Integral charging circuits for ultracapacitors which shall comply with IEC 62391-1 and IEC 62391-2 shall be provided with reliable means of protection from overvoltage charging conditions and if necessary, overcurrent charging and discharging conditions.

2) Ultracapacitors employing metal containers shall be insulated from one another and from a metal tray or metal capacitor compartment. Insulation shall be constructed to reduce the risk of damage to the insulation during the normal operation and maintenance of the truck.

3) The metal container of an ultracapacitor that is connected to the negative electrode of the capacitor (negative electrode and the metal container or not insulated internally from each other) shall be considered part of the negative electrode and shall be enclosed or provided with an insulating cover.

   ~~Ultracapacitor terminals that are threaded shall be provided with lock washers or equivalent means to reduce the risk of a loose wiring nut-terminal connection causing an external short between terminals.~~

4) Ultracapacitor terminals shall be connected in a safe way avoiding any possibility that a conductive component could connect ultracapacitor terminals generating an electric arc.

5) Ultracapacitor terminals shall be protected by insulating boots or covers, if applicable.

6) ~~Exception No. 1:~~ A terminal that is intended to be intentionally connected to ground on the truck frame ~~need not~~ can be provided with a boot or cover.

~~Exception No. 2: this requirement does not apply to a built-in ultracapacitor charger equipped with a ground-fault circuit interrupter or an isolated secondary.~~

7) Before maintenance or service of ultra-capacitors ensure they are fully discharged or the circuit shall be safely disconnected.

4.14.11 Electrical insulation

1) Materials employed as electrical insulation shall comply with ISO 1798, ISO 2440, ISO 179 (all parts), ISO 180 and ISO 877 (all parts).

2) The thickness of an insulating barrier employed as the sole insulation between uninsulated live parts and non-current carrying metal parts or between parts of opposite polarity shall be 0,71 mm thick minimum.

3) ~~Exception:~~ For a system with output rated 24 V DC or less, the thickness shall be 0,33 mm minimum.

4) For a system rated more than 24 V DC, where there is a minimum of half of the required acceptable spacing through air, a barrier or liner ~~may~~ can be employed that has a minimum thickness of 0,33 mm.

5) ~~Exception:~~ For a system rated 24 V DC or less, the thickness shall be 0,15 mm minimum.

4.14.12 Limited power circuit

A limited power circuit shall comply with the test of 5.13.

4.14.13 Electrical spacings

The spacings in a fuel cell power system for industrial trucks shall not be less than as outlined in Table 2.

~~Exception No. 1:~~ Minimum acceptable spacings are not specified in a limited power circuit as defined in 4.14.12.

~~Exception No. 2:~~ Minimum acceptable spacings within a component shall be determined by the component document.

~~Exception No. 3:~~ Minimum acceptable spacings ~~may~~ can be reduced from that outlined in Table 2 if the circuits are evaluated in accordance with IEC 60664-1, and the following:

1) The reduced spacing requirements shall not be used at electrical connections to the truck or for spacings to a non-current carrying metal enclosure.

2) The fuel cell is to be rated for overvoltage category I and pollution degree 3 as defined in IEC 60664-1. Circuits provided with protective enclosures without ventilation openings to allow for the entrance of dust, humidity and other conductive debris ~~may~~ can be considered pollution degree 2 and circuits that are in hermetically sealed or encapsulated enclosures ~~may~~ can be considered pollution degree 1.

3) In order to apply clearance B (controlled overvoltage) clearances, control of overvoltage shall be achieved by providing an overvoltage device or system as an integral part of the fuel cell.

4) All printed wiring boards are considered to have a minimum comparative tracking index (CTI) of 100 (material group IIIb).

Table 2 – Spacings

Location	Nominal voltage 24 V DC or less		Nominal voltage greater than 24 V DC [a]	
	Through air mm	Over surface mm	Through air mm	Over surface mm
In a power circuit – between a bare live part and (1) a bare live part of opposite polarity, or (2) a bare grounded part other than the enclosure	1,6 [b]	3,2 [b]	3,2 [c]	6,4 [c]
In a power circuit at a location where conductive dust cannot accumulate, such as a small totally enclosed cavity [d]	0,8	1,6	1,6	3,2
In other than a power circuit – between a bare live part and (1) a bare live part of opposite polarity, or (2) a bare grounded part other than the enclosure	1,6	1,6	1,6	1,6
In other than a power circuit at a location where conductive dust cannot accumulate, such as a small totally enclosed cavity [d]	0,8	0,8	0,8	0,8
Between any uninsulated live part and the ultimate enclosure [e]	12,7	12,7	12,7	12,7
Between any uninsulated live part and the ultimate enclosure where the enclosure is formed of 3,2 mm thick cast metal or 6,4 mm thick steel plate [e]	6,4	6,4	6,4	6,4

NOTE A circuit is considered a power circuit if it supplies a motor-control circuit that is not provided with overcurrent protection. A circuit is not considered a power circuit if it supplies a circuit with overcurrent protection.

[a] Maximum of 150 V.

[b] These spacings apply to a system not electrically connected to the frame.

[c] These spacings also apply to a nominal 24 V DC or lower-voltage system electrically connected to the frame.

[d] Such as a point where a motor terminal passes through the motor frame.

[e] If deformation of the enclosure at the point of measurement of spacings is likely, the spacings after deformation shall be as specified.

4.14.14 Separation of circuits

1) A limited power circuit shall be separated from all other circuits either by:
   a) locating the circuit in a separate enclosure,
   b) proving through-air and over-surface spacings as noted in Table 2, or
   c) the use of barriers.

2) An internal wiring insulated conductor of a limited power circuit shall be either separated by barriers or segregated from live parts connected to different circuits or provided with insulation acceptable for the highest voltage involved.

3) The barriers noted in 1)c) ~~are permitted to~~ may be bonded metal of not less than 0,51 mm thickness or of insulating material of not less than 0,71 mm thickness.

4) Conductors of circuits operating at different potential shall be reliably separated from each other unless they are each provided with insulation acceptable for the highest potential involved.

5) Electrical separation of an individual circuit shall be applied according to the requirements of IEC 60364-4-41:2005, Clause 413.

4.15 Control circuits

4.15.1 Safety controls

1) Electronic circuits relied upon for safety (a safety critical component, for example) shall be evaluated in accordance with IEC 607030-1:2013, IEC 60730-1:2013/AMD1:2015 and IEC 60730-1:2013/AMD2:2020, Annex H.

2) Software relied upon for safety as a safety critical component shall be evaluated in accordance with level C given in ISO 13849-1. The electronic hardware of the software safety system shall be evaluated in accordance with IEC 60730-1:2013, IEC 60730-1:2013/AMD1:2015 and IEC 60730-1:2013/AMD2:2020, Annex H.

3) As an alternative, electronic circuits and programmable software controls relied upon for safety can be evaluated according to IEC 61508 (all parts) or ISO 13849-1 and ISO 13849-2.

4.15.2 Start

1) The start of an operation shall only be possible when all of the safeguards are in place and are functioning in accordance with 4.16. The fuel cell power system shall be started only by an intentional operation of the start sequence unless it is determined that there is minimal risk with automatic restarting as determined by 4.16.

2) Restart of the fuel cell power system from a stop shall not result in a hazardous condition as determined by 4.16.

4.15.3 Drive off

1) The fuel cell power system shall include means to minimize the likelihood of moving the industrial truck with the fueling hose attached.

NOTE The drive off protection means can include an interlock switch in the fueling receptacle, an interlock circuit connected to the dispenser, or other means.

2) Switches, circuits, and the like used for drive off protection shall be suitable for the local area classification in which they are used. See 4.10 4).

4.15.4 Emergency stop

Fuel cell power systems shall be provided with an emergency stop mechanism.

4.16 ~~Safety/hazard analysis~~ Risk assessment and risk reduction

The manufacturer of the fuel cell power system shall conduct a ~~failure modes and effects analysis (FMEA) or other equivalent reliability analysis to identify faults that will affect the safety of the system~~ risk assessment and perform risk reduction using the principles and methodology in accordance with ISO 12100, IEC/ISO 31010, IEC 60812, and IEC 61025.

NOTE ~~Background information on FMEAs can be found in IEC 60812.~~

Hazards addressed in the risk assessment and risk reduction include but are not limited to:

a) mechanical hazards, such as sharp edges or corners, protruding parts, moving parts, rotating or sliding parts, mass, and center of gravity;

b) liquids;

c) flammable or pressurized gases;

d) risk of fire and electric shock;

e) temperature, such as hot surfaces;

f) loss of output (loss of power to the industrial truck) and loss of control.

5 Performance requirements for safety and type tests

5.1 General

1) For the tests in 5.2 to 5.22, the fuel cell power system shall operate at maximum power with controls set to maximum normal limits, unless otherwise noted in the test methods.

2) As a result of the tests in 5.2 to 5.22 there shall be no leakage from parts containing liquid or gas that would result in a hazardous condition, unless otherwise noted.

5.2 Vibration test

5.2.1 General

1) A fuel cell power system shall be subjected to a system vibration test in both the vertical and longitudinal/lateral axes in accordance with 5.2.2 and 5.2.3. The fuel cell power system shall not be operating for these tests. As a result of the tests, the fuel cell power system shall comply with 5.5 and 5.6.

2) ~~Exception:~~ If the fuel cell power system is intended for use in an industrial truck with a known vibration profile, that profile ~~may~~ can be used instead of the profile outlined in 5.2.2 and 5.2.3.

3) A self-contained fuel cell power system is to be tested outside of the truck in accordance with 5.2.2 and 5.2.3. The fuel cell power system is to be mounted using its own securement means, or a representative of the securement means, and secured to the test fixture of the vibration test apparatus in the same position which it occupies when in use.

4) An integrated fuel cell power system is not required to be tested in accordance with 5.2.2 and 5.2.3.

5) With reference to 3), individual components or sub-systems ~~may~~ can be tested by themselves so long as they are mounted and supported as they ~~would~~ can be in the complete system. Components normally mounted near the test subject ~~must~~ shall be included or simulated if there is any chance of interference or contact between the parts.

5.2.2 Vertical axis test

The acceleration data for the vertical axis test shall be defined in collaboration with the truck manufacturer.

5.2.3 Longitudinal and lateral axes tests

The acceleration data for the longitudinal and lateral axis test shall be defined in collaboration with the truck manufacturer.

5.3 Fuel container securement test

1) Means shall be provided to secure fuel containers from becoming dislodged while in use or stored on the fuel cell power system. Lateral movement shall not exceed an amount that results in a hazardous condition. Any integral compressed gas fuel container shall include a connection fixture that will not allow the flow of gas until a positive gas seal has been achieved. The fuel connection device connecting the fuel supply and the system shall be suitable for its application.

2) A lateral force equal to the full weight of the fuel container or cylinder shall be applied in any direction at the centre of the vertical height of the fuel container or cylinder. The fuel container (i.e. fuel cylinder) or any portion thereof, shall not become dislodged from its retention means.

5.4 Endurance test

1) A fuel cell power system employing nonmetallic flammable fuel handling parts and/or flammable fuel pumps with dynamic seals shall be subjected to appropriate endurance testing in accordance with 2). The fuel cell power system shall comply with 5.7, before and after the test. There shall be no damage to the fuel cell power system that would result in a hazard. The fuel cell power system shall be operational.
2) The fuel cell power system shall be connected to a source of fuel and operated at a minimum of 50 % of the ~~maximum continuous operating load conditions~~ rated power output. This shall be done continuously for 720 h under normal operating pressures and temperatures.

5.5 External leakage test

All piping shall be leak tested in accordance with ISO 15649.

~~5.5.1 External leakage – Hazardous gas containing portions (determination of dilution boundary)~~

~~1) The average measured gas concentration in the unclassified areas of the fuel cell power system near points of release or purge shall not exceed 25 % of the lower flammability limit (LFL).~~
~~2) The diluted concentrations of flammable vapours exiting the fuel cell power system shall not exceed 50 % of the lower flammability limit (LFL).~~
~~3) The fuel cell power system is to be operated under normal conditions of use until steady-state temperatures are obtained. The testing shall be carried out in a draft free area, with the system located at least 3 m from room vents or forced ventilation.~~
~~4) Flammable gas concentration measurements are to be made at the location of the unclassified equipment or the possible sources of ignition closest to possible sources of abnormal release relative to the ventilation flow path as determined in accordance with 4.15. Measurements are to be made at a maximum of 305 mm from the source of release, in locations above and horizontal to the source of release, in the center of flow.~~
~~5) The test shall be continued until four consecutive measurements have shown the increase in the flammable concentration does not exceed by more than 5 % of the mean of the four measurements. The test is to be continued until the trended average shows no increase greater than 5 % over a period of 2 h. No individual measurement over 25 % LFL shall create a hazard in accordance with 4.15.~~
~~6) The time interval between measurements shall be greater than or equal to 30 min.~~
~~7) The test is to be conducted as many times as necessary to develop sufficient data with a minimum of 2 times.~~
~~8) The test shall include at least one purge cycle, if applicable.~~

~~5.5.2 External leakage – Hazardous liquid containing portions~~

~~1) This test shall be conducted before and after the endurance test of 5.4.~~
~~2) All hazardous liquid containing portions of the system shall be subjected to a hydrostatic pressure of 1,5 times the maximum operating pressure of the system. The test pressure shall be introduced gradually into the section under test while venting any gas present until the test pressure is reached. The test pressure is then held for a minimum of 30 min.~~
~~3) For this test, water or liquid fuel specified by the manufacturer may be used.~~
~~4) During the test, there shall be no sign of liquid leakage from the system.~~

5.6 Dilution test

5.6.1 Releases

The leak rate for each potential release point in the fuel cell power system including any purge outlets shall be determined. See 4.10 and IEC 60079-10-1.

5.6.2 Setup and operation

1) The testing shall be carried out in a draft free area, with the system located at least 3,05 m from room vents or forced ventilation.
2) If the fuel cell power system uses mechanical ventilation, it shall be operated at the minimum flow rate that satisfies all interlocks. See 4.10.

5.6.3 Exhaust dilution

1) Hydrogen or equivalent gas shall be released at the determined leak rate and at the location of the largest potential release point in the fuel cell power system.
2) The diluted concentrations of flammable vapours exiting the fuel cell power system shall not exceed the limits of 4.10 2).

5.6.4 Dilution boundaries

1) Hydrogen or equivalent gas shall be released at the determined leak rate at each potential release point in the fuel cell power system.
2) The size and shape of each dilution zone shall be measured using a calibrated hydrogen or equivalent gas detector.
3) The analysis of 4.10 3) shall be confirmed or updated with the measured sizes and shapes of the dilution zones.
4) The requirements of 4.10 4) and 6) shall be confirmed with the measured sizes and shapes of the dilution zones.

NOTE In some cases it can be sufficient to place the hydrogen or equivalent gas detector at the locations of the nearest ignition source or unclassified equipment above and in the ventilation flow path, i.e. "downwind", of the release.

5.7 Ultimate strength test

~~#### 5.6.1 Ultimate strength – Hazardous liquids and pressurized parts~~

~~1) All parts conveying hazardous liquids and any other liquids under pressures of 206,8 kPa or greater are to be subjected to this test.~~
~~2) The parts under test are to be subjected to a hydrostatic pressure of 1,5 times the maximum allowable working pressure, which is to be introduced into the parts under test gradually, eliminating any gas, and then held at that pressure for a minimum of 5 min (according to the pressure vessel guidelines). Portions of the system at different pressures may each be tested separately at the appropriate test pressure.~~
~~3) Either water or another suitable test liquid, with similar properties to the liquid used in the system, may be used for this test.~~
~~4) The parts of the system subjected to this test shall withstand the test pressure without rupture, fracture, permanent deformation after pressure is removed, or other physical damage.~~

~~#### 5.6.2 Ultimate strength – Hazardous gas and pressurized parts~~

~~1) All parts conveying flammable gas and any other gas conveying parts at pressures of 206,8 kPa or greater are to be subjected to this test.~~
~~2) The parts under test are to be subjected to a hydrostatic test at 1,5 times their maximum allowable working pressure (MAWP). If liquid test medium is not practical, the parts under test can be subjected to a pneumatic pressure test using air or other inert gas at 1,1 times their maximum allowable working pressure. The test pressure is to be gradually introduced. When conducting a hydrostatic pressure test, all gas remaining in the parts under test is to be released. When the test pressure is achieved, it is to be held for a minimum of 1 min.~~
~~3) Parts that are pressurized shall not show signs of rupture, fracture, deformation or other physical damage.~~

~~5.6.3 Ultimate strength – Fuel cell modules~~

1) A fuel cell module shall comply with the allowable working pressure test requirements of IEC 62282-2-100.

2) The oxidant and fuel sides of the cell stack ~~may~~ can be interconnected and tested simultaneously at the same pressure.

5.8 Potential failure modes test

1) A review of the manufacturer's hazard analysis in accordance with 4.16 is done to determine the scope of this test procedure, including whether or not the system is to be operating during the test. Compliance with 5.8 ~~may~~ can also be determined through supporting evidence provided by the manufacturer.

2) Critical failure modes, as ~~defined~~ identified in 4.16, are to be simulated to determine if the safety system is functional ~~and a safe shutdown of the system occurs~~.

3) Compliance with 5.8 shall be determined by ~~the safe shutdown~~ performance of the correct actions by the safety system in accordance with the manufacturer's ~~hazard analysis, upon initiation of a critical failure mode~~ risk assessment and risk reduction of 4.16.

5.9 Temperature test

1) ~~With the fuel cell system operating under maximum continuous load rating conditions, temperatures shall not reach a level high enough to cause a risk of a fire or damage to materials used, and temperatures measured on accessible surfaces and temperature-sensitive components and materials shall comply with Table 3.~~

   A fuel cell system shall not attain a temperature at any point so as to result in a risk of fire, to damage any material used or to exceed the maximum temperatures specified in Table 3 when the unit operates at maximum rated output power in an ambient temperature as specified in 3).

2) A thermal or overload protective device shall not operate during this test.

3) All temperature rise values in Table 3 are based on an assumed ambient temperature of 25 °C. Tests ~~may~~ can be conducted at any ambient temperature within the range of 10 °C to 40 °C when ~~it is~~ measured values are corrected by addition (if the ambient temperature is lower than 25 °C) or subtraction (if the ambient temperature is higher than 25 °C) of the difference between 25 °C and the ambient temperature.

4) Testing shall be continued until steady state temperatures are attained. Steady state temperatures are achieved when three successive readings taken at intervals of not less than 5 min indicate ~~no further~~ an increase in temperature less than 0,5 °C.

5) Temperatures shall be measured by means of thermocouples. Temperatures on coil windings ~~may~~ can be measured by either thermocouples or change of resistance method.

6) Thermocouples shall consist of wires not larger than 0,21 mm^2 and not smaller than 0,05 mm^2. The thermocouple wire shall conform to the requirements specified in the tolerances on initial values of EMF versus temperature tables in IEC 60584-1.

7) When using the resistance method, the windings shall be at room temperature at the start of the test, and the temperature rise of a winding is to be calculated using the following formula:

~~$$\Delta t = \frac{R}{r}(k + t_1) - (k + t_2)$$~~

$$\Delta t = \frac{R}{r}(k + t_1) - (k + t_2)$$

where

Δt is the temperature rise, expressed in °C;

R is the resistance of the coil, expressed in Ω at the end of the test;

r is the resistance of the coil, expressed in Ω at the beginning of the test;

t_1 is the initial room temperature, expressed in °C at the time resistance;

"r" is being measured (which is also the initial coil temperature);

t_2 is the room temperature, expressed in °C at the end of the test; and

k is 234,5 for copper and 225,0 for electrical conductor grade (EC) aluminium; values of the constant for other conductors are to be determined.

Table 3 – Temperature rise limits

Material and components	Temperature rise limits °C
Motors:	
Class 105 (A) insulation systems	
Thermocouple method	65
Resistance method	75
Class 130 (B) insulation systems	
Thermocouple method	85
Resistance method	95
Class 155 (F) insulation systems	
Thermocouple method	110
Resistance method	120
Class 180 (H) insulation systems	
Thermocouple method	125
Resistance method	135
Coils other than motors:	
Class 105 (A) insulation systems	
Thermocouple method	65
Resistance method	75
Class 130 (B) insulation systems	
Thermocouple method	85
Resistance method	95
Class 155 (F) insulation systems	
Thermocouple method	110
Resistance method	120
Class 180 (H) insulation systems	
Thermocouple method	125
Resistance method	135
Conductors:	
Rubber or thermoplastic insulated wires and cords (unless rated for higher temperatures)	35
Surface temperatures of components (unless rated for higher temperatures):	
Electrolytic capacitors [a]	~~40~~ –
Other capacitors [a]	~~65~~ –
Fuses	65

Material and components	Temperature rise limits °C
Electrical insulation (where deterioration would result in a safety hazard):	
Fibre	65
Laminated phenolic	100
Moulded phenolic	125
Other insulation materials [a]	–
Non-metallic enclosure, structural and functional materials [a]	–
Safety critical gaskets and seals [a]	–
Supporting and adjacent surfaces	65
A surface subject to continuous contact while the fuel cell power system is in use such as a momentary contact switch, etc.:	
Metallic	50
Non-metallic	60
A surface subject to deliberate contact while the fuel cell power system is in use, but not subject to continuous contact such as a switch:	
Metallic	60
Non-metallic	85
A surface subject to casual contact:	
Metallic	65
Non-metallic	83
[a] Temperature limits are dependent on the temperature rating of the material.	

5.10 Continuity test

1) Portions of the fuel cell power system intended to be bonded to the truck for electrostatic discharge protection shall be subjected to a bonding test.
2) ~~Metallic~~ Conductive parts required to be bonded to avoid electrostatic discharge shall have the impedance measured with a suitable ohmmeter between all points of connection of the metallic parts to determine that the resistance does not exceed 1 Ω.
3) Nonmetallic fluid lines shall have a maximum resistivity of 1 MΩ when evaluated in accordance with the conductivity test in IEC 60079-0 (the test will identify the required protection level and has standard references for the protection level).

~~**5.10 Touch current test**~~

~~1) A fuel cell power system with circuits and/or outputs greater than 42,4 V peak (60 V d.c. or 30 V r.m.s.) shall be subjected to the measurement of touch current test in 2) to 7) of 5.10.~~

~~2) The measured touch current limit for a fuel cell power system when tested in accordance with 3) of 5.10 shall not be more than~~

~~a) 0,5 mA for a.c. circuits, and~~

~~b) 2,0 mA for d.c. circuits.~~

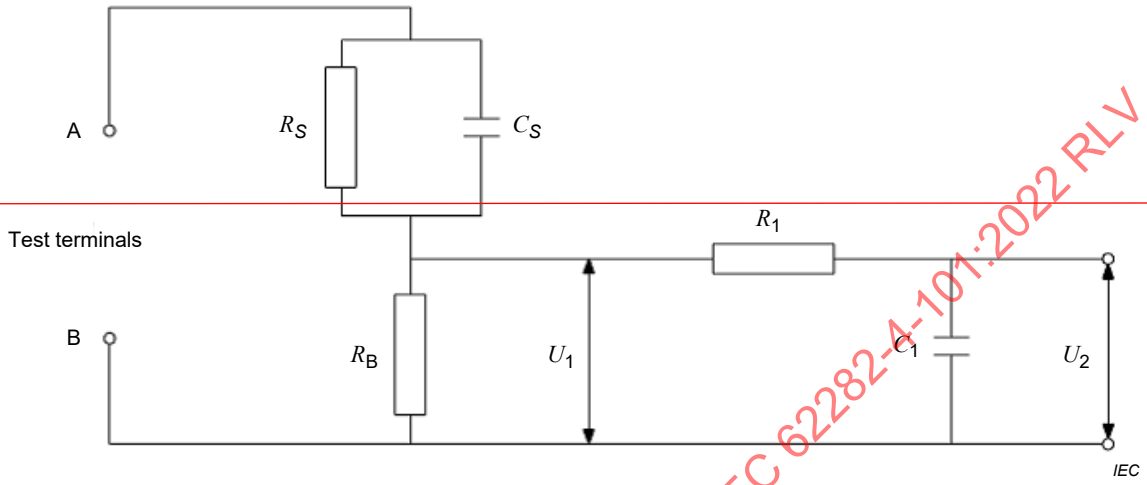
~~3) All exposed conductive surfaces of equipment shall be tested for touch current. If a conductive surface other than metal is used for the accessible parts, the touch current shall be measured using metal foil with a maximum area of 10 mm × 20 mm in contact with the surface.~~

~~NOTE The metal foil has the largest area possible on the surface under test without exceeding the dimensions specified.~~

4) During the test, the fuel cell power system shall be operated at maximum continuous operating load and insulated from ground. Touch current shall be measured with the fuel cell power system in a thermally stabilized condition as in 5.9.

5) Testing shall be conducted with any single pole switches in both the on and off positions.

6) The measuring network for touch current weighted for perception or reaction is shown in Figure 5.



Key

R_S = 1 500 Ω R_1 = 10 000 Ω

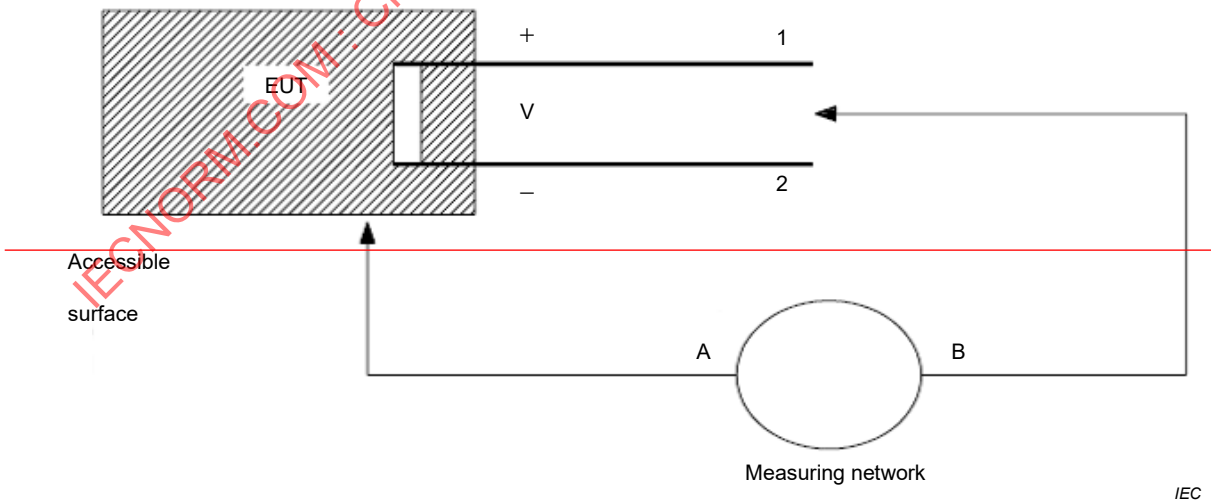
R_B = 500 Ω C_1 = 0,022 μF

C_S = 0,022 μF

NOTE Voltage U_2 is the frequency-weighted value of U_1 so that a single, low frequency equivalent indication of touch current results for all frequencies present above 15 Hz. The weighted value of touch current is taken as the highest value of U_2 measured during testing divided by 500 W. Measurements for d.c. are made in a similar manner, but the value of touch current is taken as simply U_1 divided by 500 W.

Figure 5 – Measuring network, touch current weighted for perception or reaction

7) The arrangement of the test and connection of the test meter to the fuel cell power system under test is as illustrated in Figure 6 .



NOTE Test probe B is connected to output terminal 1 and then 2.

Figure 6 – Diagram for touch current measurement test

5.11 Non-metallic tubing test for accumulation of static electricity

5.11.1 Passing criteria

No sparks shall be observed when a grounded metal sphere is brought into gradual contact with the non-metallic tubing after it has been electrostatically charged.

5.11.2 Test method

Three samples of the tubing with ground point electrodes (i.e. metal fittings) shall be conditioned for at least 48 h at a relative humidity of (25 ±10) %.

Immediately after removal from the low-humidity chamber, the samples are to be supported by means of insulators in a room having a relative humidity not more than 35 % and having all sources of light, other than electrical sparks, eliminated. The ground point electrodes are to be grounded. An electrostatic charge is to be sprayed on nonconductive parts of the product using an electrostatic generator limited to 5 000 V.

A 9,5 mm diameter grounded metal sphere is to be brought into gradual contact with the sample. If no sparks appear, the sample passes the test.

5.12 Dielectric voltage – Withstand test

1) Each ~~high-voltage~~ circuit (greater than 30 V RSM or 42,4 V peak or 60 V DC) of the fuel cell power system shall withstand, without breakdown, the application of an essentially sinusoidal potential at 50 Hz or 60 Hz of 1 000 V plus twice the rated voltage of the circuit if ~~the truck system~~ it is rated more than 72 V, or 500 V otherwise. Semiconductors or similar electronic components liable to be damaged by application of the test voltage ~~may~~ can be bypassed or disconnected.

   ~~Exception:~~ DC potential equal to 1,414 times the value for the AC potential ~~may~~ can be applied instead.

2) The test voltages shall be applied for a minimum of 1 min.

5.13 Limited power circuit test

1) A limited power source shall comply with one of the following:
   a) the output is inherently limited in compliance with Table 4;
   b) an impedance limited output in compliance with Table 4. If a positive temperature coefficient device is used, it shall comply with IEC 60730-1:2013, IEC 60730-1:2013/AMD1:2015 and IEC 60730-1:2013/AMD2:2020, Clause 15, Clause 17 and Annex J;
   c) a non-arcing over-current protective device is used and the output is limited in compliance with Table 5;
   d) a regulating network limits the output in compliance with Table 4 both under normal operating conditions and after any single fault conditions in the regulating network (open circuit or short circuit); or
   e) a regulating network limits the output in compliance with Table 4 under normal operating conditions and a non-arcing over-current protective device limits the output in compliance with Table 5 after any single-fault condition in the regulating network (open circuit or short circuit). If the overcurrent protection means is a discreet arcing device, further evaluation with respect to its isolation from potentially flammable gas ~~vapours~~ should be made.

NOTE The reason for making measurements with overcurrent protection means bypassed is to determine the amount of energy that is available to cause possible overheating during the operating time of the overcurrent protection means.

2) The load referenced in footnotes b) and c) of Table 4 and Table 5 shall be adjusted to develop maximum current and power transfer, respectively. Single faults in a regulating network are applied under these maximum current and power conditions.

Table 4 – Limits for inherently limited power sources

Output voltage direct current [a] V_{oc}	Output current [b] I_{sc}	Apparent power [c] ~~|S|~~ S
~~V_{dc}~~ V	A	VA
≤ 20	≤ 8,0	≤ 5 × V_{oc}
20 < V_{oc} ≤ 30	≤ 8,0	≤ 100
30 < V_{oc} ≤ 60	≤ 150 / V_{oc}	≤ 100

[a] V_{oc}: Output voltage measured with all load circuits disconnected. Voltages are for ripple-free, direct current.

[b] I_{sc}: Maximum output current with any non-capacitive load, including short circuit, measured 60 s after application of load.

[c] S (VA): Maximum output VA with any non-capacitive load measured 60 s after application of load.

Table 5 – Limits for power sources not inherently limited (overcurrent protection required)

Output voltage [a] V_{oc}	Output current [b] I_{sc}	Apparent power [c] ~~|S|~~ S	Current rating of overcurrent protection [d]
~~V_{dc}~~ V	A	VA	A
≤ 20			≤ 5,0
20 < V_{oc} ≤ 30	≤ 1 000/V_{oc}	≤ 250	≤ 100/V_{oc}
30 < V_{oc} ≤ 60			≤ 100/V_{oc}

[a] V_{oc}: Output voltage measured with all load circuits disconnected. Voltages are for ripple free, direct current.

[b] I_{sc}: Maximum output current with any non-capacitive load, including short circuit, measured 60 s after application of load. Current limiting impedances in the equipment remain in the circuit during measurement, but overcurrent protection means are bypassed.

[c] S (VA): Maximum output VA with any non-capacitive load measured 60 s after application of load. Current limiting impedances in the equipment remain in the circuit during measurement, but overcurrent protection means are bypassed.

[d] The current ratings of the overcurrent protection means are based on fuses and circuit-breakers that break the circuit within 120 s with a current equal to 210 % of the current rating specified in the table.

5.14 ~~Maximum VA test~~ Rated power output test

1) One sample of the fuel cell power system shall be subjected to a ~~maximum VA~~ rated power output check in accordance with 3) and 4).

2) The duration of the rated power output check shall be determined by the manufacturer.

NOTE The maximum current is expected to continue for 3 h (or more) to define continuous load.

3) With the output of the fuel cell power system connected to a variable load, the ~~maximum VA~~ rated power output of the system is to be measured ~~for 60 s~~. The load shall be capable of being varied from zero to short circuit during the test.

4) The rated power output ~~VA~~ of the system shall not exceed the marked rated output value, (see Clause 7 2)c)), by more than ±10 %.

5.15 Abnormal operation test – Electric equipment failures

1) The fuel cell power system shall be subjected to the electrical component faults noted in 2) to 4). The introduced faults of the electrical components shall not result in a shock or fire hazard from the fuel cell power system.

2) The fault conditions are to be maintained for 7 h or until ultimate results occur. Ultimate results include thermal stabilization of the system or the opening of a fuse or other protective device.

3) The following fault conditions, as applicable to the system, are to be conducted:

   a) the fuel cell power system output short-circuited;

   b) the rotor of each blower or fan motor locked, one at a time, if the system relies upon forced ventilation;

   c) the polarity of batteries reversed, if the batteries employed in the system are user replaceable or the battery connector is not polarized;

   d) the fuel cell power system operating at maximum available power as determined by ~~maximum VA~~ rated power output in 5.14, unless a fuse opens;

   e) the system operating at 135 % of the ampere rating of the protective fuse, with the fuse bypassed, if a fuse operates during condition d); and

   f) the absence of liquid supplied for liquid pumps that require a liquid for cooling purposes.

4) If a protective device opens during conditions 3)a) to 3)d) and 3)f), the test shall be

   a) terminated, if a non-resettable, non-automatic protector functions;

   b) continued for 7 h if an automatic-reset protector functions, or

   c) continued for 10 cycles at a rate not faster than 10 operations/min if a manual reset device operates.

5.16 Emission of effluents test (only for methanol fuel cells)

1) A methanol fuel cell power system capable of producing emissions of any materials given in Table 6 shall not exceed the emission limit in Table 6.

2) The methanol fuel cell power system shall be operated at rated power in an open room or outdoors. During the operation, a sufficient effluent sample shall be secured to allow a determination of compliance with Table 6.

3) The effluent sample shall be secured at a point of exhaust discharge of the methanol fuel cell power system. The results of the analyses shall be compared to the limits in Table 6. If the measured rate is less than the limit, the direct methanol fuel cell power system passes the test.

Table 6 – Emission rate limits

	Emission rate limit
Methanol	1,8 g/h
CO	0,20 g/h
CO_2	No limit

5.17 Environmental test

~~**5.17.1 General**~~

~~A fuel cell power system fuel by methanol shall not create a hazardous or unsafe condition when exposed to winds having nominal velocities up to and including 16 km/h. Compliance with this clause is demonstrated by testing according to 5.17.3.~~

5.17.1 Rain test

Enclosures shall be compliant with IPX4 in accordance with IEC 60529. Compliance with ~~this clause~~ IPX4 is demonstrated by testing required by IEC 60529. The external enclosure of the fuel cell power system shall comply with the appropriate testing requirements in accordance with IEC 60529, based the requirements of 4.13 2) and the IP rating of the product marked on the nameplate. See Clause 7 2)j).

IPX2 is acceptable for units designed and labelled for indoor operation only.

5.17.2 Test of equipment – Exposure to wind

1) ~~A fuel cell power system marked with a maximum wind speed in accordance with 2) k) of Clause 7 shall be subjected to this test for exposure to winds.~~ A fuel cell power system fueled by methanol shall not create a hazardous or unsafe condition when exposed to winds having nominal velocities up to and including 16 km/h. Compliance with harmful effect is demonstrated by testing according to 2) to 4).
2) The fuel cell power system shall not be adversely affected by wind.
3) The fuel cell power system shall operate without damage or malfunctioning of any part and without creating a hazardous condition when exposed to winds having nominal velocities of 50 km/h or the manufacturer's rated maximum wind speed marked on the product, whichever is higher.
4) A wind produced by a fan or blower having a velocity of 50 km/h or the manufacturer's rated maximum wind speed marked on the product, whichever is higher, is to be directed against an outer surface of the fuel cell power system at directions considered worse case. The fan or blower is to be located so that a uniform wind, covering the entire projected area of the outer surface of the system, is directed horizontally toward the fuel cell power system at the specified velocity measured in a vertical plane 457,2 mm from the windward surface of the fuel cell power system.

5.18 Enclosure tests

5.18.1 Enclosure loading test

The self-contained fuel cell power system's external enclosure housing shall be constructed so that a loading force of 1 110 N, applied for 1 min on the top of the external enclosure, does not cause damage to the fuel cell, shorting of electrical spacings within the fuel cell, or other hazards.

~~A 1 110 N force shall be applied to any 930 cm^2 area of the top of the enclosure for a period of 1 min, when a fuel cell power system includes a top of the enclosure.~~

5.18.2 Test for thermoplastic enclosures

5.18.2.1 Impact test

A thermoplastic external enclosure shall comply with ~~the in accordance with~~ IEC 60695-10-2. The enclosure shall also be subjected to an impact of 136 J. The impact test is to be conducted by dropping a steel sphere, 101,6 mm in diameter and weighing 4,5 kg, from a height of 3,0 m.

5.18.2.2 Cold impact test

A fuel cell power system intended for cold temperature use marked for use at or below –20 °C in accordance with Clause 7 2)f) that utilizes a thermoplastic external enclosure shall comply with the cold impact test, minus 30 °C conditioning or 10 °C below the marked rated temperature, whichever is lower, in accordance with IEC 60695-1-30 and IEC 60695 (all parts), except that the enclosure shall be subjected to an impact of 136 J during the test. The test shall be conducted by dropping a steel sphere, 101,6 mm in diameter and weighing 4,5 kg, from a height of 3,0 m.

5.18.2.3 Mould stress test

1) A thermoplastic external enclosure of a fuel cell power system shall be suitable for the range of temperatures that it is subjected to during use.
2) A thermoplastic enclosure shall be subjected to the test in accordance with IEC 60695-10-2.
3) As a result of the mould stress test, there shall be no warping, melting or other deformation of the external enclosure that would expose hazardous parts, or affect ventilation or other systems that could affect safe operation of the fuel cell power system.

5.18.2.4 20 mm moulded part needle flame test for thermoplastic materials

1) As an alternative to classifying thermoplastic external enclosure materials as V-0 or V-1, a 20 mm flame test of the moulded part(s) as outlined in 5.19 2) to 4) ~~may~~ can be conducted.
2) The test shall be conducted by employing the apparatus and test flame described in IEC 60695-11-4.
3) Two 30 s applications of the tip of the 20 mm flame shall be made to each section of the enclosure selected as indicated above, with 1 min intervals between applications. A supply of technical grade methane gas shall be used with a regulator and meter for uniform gas flow.
4) The enclosures shall not flame for more than 1 min after two 30 s applications of a test flame with an interval of 1 min between applications of the flame. The results are not acceptable if the sample is completely consumed.

5.19 Marking plate adhesion test

1) To determine if a marking plate secured by adhesion complies with Clause 7, representative samples shall be subject to 2) to 5). In each test, three samples of the marking plates shall be applied to the same test surfaces as employed in the intended application.
2) Immediately following each of the tests in 3) to 5) and after exposure to room temperature for 24 h, each sample shall
   a) demonstrate good adhesion and the edges shall not be curled,
   b) resist defacement or removal as demonstrated by scraping across the test panel with a flat metal blade 1,76 mm thick, held at a right angle to the test panel, and
   c) have legible printing that is not defected by rubbing with thumb or finger pressure. Printing should resist removal from general cleaning chemicals or by rubbing with thumb or finger pressure.
3) For air-oven ageing, three samples of the marking plates shall be placed in an air-circulating oven maintained at a temperature of 85 °C for 240 h.
4) For immersion testing, three samples of the marking plates shall be placed in a controlled atmosphere maintained at (23 ± 2) °C with a (50 ± 5) % relative humidity for 24 h. The samples shall then be immersed in water at a temperature of (23 ± 2) °C for 48 h.
5) For standard atmosphere testing, three samples of the marking plates shall be placed in a controlled atmosphere, maintained at (23 ± 2) °C with (50 ± 5) % relative humidity for 72 h.

5.20 Test for elastomeric seals, gaskets and tubing

5.20.1 General

Elastomeric seals, gaskets and tubing relied upon for safety shall be subjected to the test in 5.20.2 and in 5.20.3, as applicable.

5.20.2 Accelerated air-oven ageing test

Elastomeric seals, gaskets and tubing relied upon for safety shall be suitable for temperatures encountered and shall comply with the test in accordance with ISO 16010.

5.20.3 Cold temperature exposure test

1) Elastomeric seals, gaskets and tubing relied upon for safety and intended for extreme cold temperature use systems rated at or below –20 °C shall not become brittle to the extent that they will not function as intended as a result of 2).
2) Parts described in 5.20.1 shall be subjected to the test in accordance with ISO 16010.

5.20.4 Immersion test

Elastomeric seals, gaskets and tubing relied upon for safety shall be suitable for exposure to fluids such as methanol encountered in use and shall comply with the volume change test in Liquid B in accordance with ISO 16010 except that the test liquid shall be representative of the

liquid the material will be exposed to (i.e. 100 % methanol or a methanol blend) and the volume change allowed shall be (25 ±1) % of the as-received value.

5.21 Test for permeation of non-metallic tubing and piping

1) Non-metallic tubing and piping containing flammable gas ~~and vapours~~ shall be sufficiently nonpermeable to those gases ~~and vapours~~.
2) Non-metallic tubing and piping shall be subjected for permeability to hydrogen in accordance with ISO 4080.

5.22 Test for electrical output leads

1) The electrical output power leads of a fuel cell power system intended for exposure to extreme temperatures above 50 °C and at or below –20 °C shall be constructed so that they can withstand the test in 2) based upon the extreme temperatures as marked in accordance with Clause 7 2)f). These tests do not apply to low-voltage circuits.
2) Parts described in 1) shall be subjected to the test in accordance with ISO 16010, at 10 K higher than the marked temperature rating, but no less than 70 °C for 168 h. After conditioning, the leads shall be examined for signs of deterioration such as cracking and melting.

~~Exception:~~ Leads with insulation marked with a temperature rating meeting the high temperature marked on the system in accordance with Clause 7 2)f) are not required to be subjected to this test.

5.23 Emergency stop

1) The effectiveness of each emergency stop actuator and device shall be confirmed by test.
2) The fuel cell power system shall be energized sufficiently to perform the test. Circuits and components can be energized using batteries or external sources rather than operating the fuel cell using a flammable gas as long as all emergency stop functions can be confirmed.
3) Each emergency stop actuator and device is to be activated individually.
4) The stopping and removal of power to each individual fuel cell power system actuator controlled by the emergency stop is to be confirmed for each emergency stop actuator and device. Fuel cell power system actuators can include motors, valves, pumps, blowers, fans, and the like.

6 Routine tests

6.1 External leakage

1) An external leakage on the flammable fluid containing portions of the system shall be subjected to an external leak test on 100 % of the production.
2) While under normal operating pressures, the gas containing portions of the system shall not leak after operation for 1 min. Visible signs of soap bubbles, pressure decay or similar occurrences, as applicable to the method of test, shall indicate leaks in the system.
3) The fuel cell power system shall be operated, or the parts under test pressurized at normal operating pressure. Areas for potential leaks such as at fittings are to be tested for leaks using a soap and water leak detection solution or equivalent means.

6.2 Dielectric voltage-withstand test

The test in 5.12 shall be conducted on 100 % of the production except that the time can be lowered to 1 s if the test potential is increased by 120 % of the rated voltage (1 000 + 2,4 × V_{rated}).

~~Exception:~~ This production line test is not required to be conducted on low-voltage circuits.

7 Markings

1) The nameplate markings specified in 2) shall be permanently secured to the fuel cell power system. If an adhesive is used to secure the marking plate on the fuel cell, then the adhesive shall comply with the test of 5.19.

2) The fuel cell power system marking plate shall include the following:

   a) the manufacturer's name, trademark or other descriptive marking by which the organization responsible for the product can be identified;

   b) a catalogue number or the equivalent;

   c) output electrical rating in nominal system volts, maximum continuous amperes and the ~~maximum VA~~ rated power output;

   d) type of fuel utilized, including service pressure and maximum operating pressure;

   e) where the fuel tank is fixed and not easily viewed, the label shall include the total fuel container water volume, in litres, along with the re-test date(s) or expiration date;

   f) minimum and maximum ambient operating temperatures;

   g) minimum and maximum storage temperatures, if different from f);

   h) weight of the fuel cell power system, for self-contained systems only;

   i) centre of gravity of the fuel cell power system, for self-contained systems only; and

   j) an IP rating ~~may~~ shall be provided on a fuel cell power system ~~intended to be evaluated to a minimum IP rating~~ that complies with 4.13 1), 2), and 3), and 5.18.1;

   ~~k) a marking of maximum wind speed for fuel cell power systems (intended to be exposed to elevated wind speeds up to 50 km/h or the manufacturer's rated maximum wind speed marked on the product, whichever is higher).~~

3) All other required markings in a) to h) shall be permanent in accordance with IEC 60950-1:2005, 1.7.11:

   a) a fuel cell power system intended for field installation shall also include a marking indicating that the system is intended for field installation by qualified personnel only;

   b) systems provided with replaceable fuses shall be marked with the current and voltage rating of the fuse near the fuse holder;

   c) the polarity of the output leads shall be marked on the leads unless they are terminated in a polarized connector;

   ~~d) Fuel tanks provided for the system shall be marked with the appropriate fuel and pressure.~~

   d) the fuel cell power system shall be marked to indicate that it has to be properly connected to the truck equipotential bonding system;

   e) with reference to 4.6 4), where a manual valve is used for flammable gas supplied to the fuel cell power system, the valve shall be indicated with a marking of the words "MANUAL SHUTOFF";

   ~~g) All documentation and nameplates of pressure vessels shall reflect the standard the pressure vessels meet and the relevant maintenance and testing required.~~

   f) nameplate and documentation of tanks shall include the effective end of service date of the pressure vessels based upon the worse case analysis;

   g) markings shall be in the language(s) of the country in which the truck is to be used, in accordance with national law (ISO 3691-1). A pictogram is also sufficient; and

   h) the use of symbols should also be in accordance with ISO 7010 and/or ISO 3864-1.

8 Instructions

8.1 General

1) The fuel cell power system shall be provided with an instruction manual in the national language of the operation country.

2) The instruction manual shall include maintenance, operating and installation instructions in accordance with 8.2 to 8.4.

3) The instruction manual shall include ~~a wiring diagram and a fuel line layout drawing~~ a sufficient electrical and fuel line documentation to install, operate, and maintain the fuel cell power system. This documentation shall include all information necessary to connect the fuel cell power system to the truck, refuel the fuel cell power system, and replace any regular maintenance items.

4) The operating and storage instructions shall describe the possible hazards resulting from the use of fuels and any precautions to be taken when handling the materials.

5) Information giving requirements for installation, maintenance, charging and handling shall be included in the fuel cell and/or truck installation manual.

6) The manual shall include information about recycling and handling of a damaged fuel cell.

8.2 Maintenance instructions

The maintenance instructions shall include the following, as applicable:

1) For a fuel cell power system provided with replaceable batteries, instructions for battery replacement including the type and rating of the batteries.

2) For a fuel cell power system with replaceable fuses, instructions for replacement of fuses including the type, voltage and current rating of the fuses.

~~c) Instructions indicating that the area in which a fuel cell power system is employed shall be free of flammable and combustible materials such as gasoline.~~

3) Instructions regarding the need to keep all ventilation and exhaust openings from becoming blocked so that air is not obstructed and that any required clearances to maintain suitable ventilation and exhaust shall be maintained when installed in the truck.

4) Instructions for basic inspection and maintenance such as filter cleaning, replacement of parts, and lubrication of parts. See also 4.14.2 6).

5) The source for replacement parts.

6) An explanation of the necessity for, and the minimum frequency of, periodic examinations and inspections by qualified personnel. For example, the checking of any safety critical components requiring calibration such as gas detectors and pressure switches.

7) The fuel cell display shall show if maintenance is necessary or the fuel cell manufacturer shall specify when maintenance is necessary and indicate it.

8.3 Operating instructions

The operating instructions shall include the following, as applicable:

1) Instructions for starting up and shutting down the fuel cell power system.

2) Complete instructions for the proper refuelling of the fuel cell power system including a warning not to drive or move the truck with the refueling hose or interface cable connected.

3) For a fuel cell power system with no IP rating for ingress of water, the statement

"WARNING: not rated for use in high humidity up to 95 %, wet, or rainy conditions."

4) For a fuel cell power system not designed for temperature extremes, the statement,

"WARNING: not rated for use below ___ degrees. Not rated for use above ___ degrees."

5) Information regarding provisions for adequate process and ventilation air. This shall include the following statement "This fuel cell power system uses oxygen from the area in which it is being used. It should not be used in a confined space or unusually tight construction, unless provisions are provided for adequate process and ventilation air." An example for determining the volume of a typical area should also be included.

NOTE Unusually tight construction is considered as construction where

1) walls and ceiling exposed to the outside atmosphere have a continuous water vapour retarder with a rating of 6×10^{-11} kg/(m^2 × Pa × s) (1 perm) or less with openings gasketed or sealed;

2) weather stripping has been added on windows and doors that are able to be opened; and

3) caulking or sealants are applied to areas such as joints around window and door frames, between sole plates and floors, between wall-ceiling joints, between wall panels, at penetrations for plumbing, electrical and gas lines, and at other openings.

8.4 Installation instructions

1) Instructions shall be provided for the proper installation of the fuel cell power system including, but not limited to, spacings requirements, location of ventilation and exhaust openings, securement, electrical connections and fuel connections. Where a hazard ~~may~~ can be present through system orientation or positioning, instructions shall be provided and the system so labelled.

2) The installation instructions shall have instructions regarding the proper equipotential bonding of the fuel cell power system to the truck ~~grounding means~~ chassis, see 4.11 5).

3) If storage tanks are provided, instructions for the proper installation of the storage system including instructions for the connections of the fuel lines to the fuel cell power system shall be included.

4) The installation instructions for a field installed fuel cell power system shall include a statement indicating that the system is intended for field installation by qualified personnel only.

Annex A
(informative)

Comparison of pressure terms

Comparison of pressure terms is given in Table A.1 as information.

Table A.1 – Comparison table of pressure terms

Pressure terminology	Standards/codes				
	~~ISO/TS 15869 (2009)~~ ISO 19881 (2018)	NFPA 52 (~~2010~~2019)	ASME B & PV Code Sec. VIII	SAE J2600 (~~2002~~2015)	UL 2267 (~~2006~~2020)
Service pressure (SP)	–	Same as NWP	–	–	25 Mpa or 35 MPa
Nominal working pressure (NWP) or just working pressure (WP)	WP same as NWP or SP	–	–	Same as SP	–
Maximum operating pressure (MOP)	–	1,25 × SP, same as MFP	–	1,25 × NWP, same as MFP	1,25 × SP, 31,25 MPa or 43,75 MPa
Maximum fill pressure (MFP)	1,25 × WP, same as MOP	–	–	1,25 × NWP, same as MOP	–
Design pressure	–	–	DP	–	–
Maximum allowable working pressure (MAWP)	–	1,38 × SP	MAWP	1,38 × NWP	1,38 × SP, 34,5 MPa or 48,3 MPa

Annex B
(informative)

Significant hazards, hazardous situations and events dealt with in this document

Requirement	Relevant yes / no?	Fulfilled by
1. Principles of safety integration	Yes	Application IEC Guide 116
2. Requirements regarding design and construction		
2.1 Protection against electric shock and other electrical hazards		
• leakage current (e.g. due to insulation fault)	Yes	4.14.13
• energy supply	Yes	4.14.7
• stored charges	Yes	4.14.10
• switching arc and arc fault	Yes	4.11, 4.14.2, 4.14.3
• electric shock	Yes	5.10, 5.12, 6.2
• burns	Yes	4.4
2.2 Protection against fire hazards		
• external ignition	Yes	5.15
• internal ignition	Yes	5.15
2.3 Protection against mechanical hazards		
• instability	Yes	5.4
• break-down during operation	Yes	5.4
• falling or ejected objects	Yes	4.16
• rough surfaces, sharp edges or corners	Yes	4.13, 4.16
• moving parts, especially where there may be variations in the rotational speed of parts	Yes	4.14.5, 4.16
• vibration	Yes	5.2
• improper fitting of parts	Yes	4
2.4 Protection against other hazards		
• explosion caused by the equipment itself or by substances which may be produced, emitted or used by the equipment	Yes	5.8
• implosion	Yes	5.7
• acoustic noise	No	
• excessive temperature of materials ejected or accessible non-working surfaces likely to be touched	Yes	5.9
• adverse biological and/or chemical phenomena	Yes	4.12
• hygiene conditions	Yes	4.12

Requirement	Relevant yes / no?	Fulfilled by
• emissions, production and/or use of hazardous substances (e.g. gases, liquids, dusts, mists, vapour)	Yes	4.12, 5.16
• ageing of materials	Yes	5.4
• unattended operation	No	
• connection to and interruption from power supply	Yes	4.14.12
• combination of equipment	Yes	4.14.14
2.5 Protection against hazards arising from incorrect functioning		
• expected environmental conditions, including electric, magnetic and electromagnetic disturbances considered as relevant in the product or generic EMC standard	Yes	5.8
• logic errors in hardware or software	Yes	4.16
• interruptions or normally expected fluctuations in the power supply	Yes	4.14.12
• unexpected starting or stopping operation	Yes	4.15
• failure to stop or to start	Yes	4.15
2.6 Protection against hazards arising from electric, magnetic, and electromagnetic fields, other ionizing and non-ionizing radiation	Yes	4.11, 4.14.1
2.7 Ergonomics	No	
3. Information requirements		
• Information provided with the equipment shall include instructions for safe installation, maintenance, cleaning, operation and storage.	Yes	8.2, 8.3
• Where risks remain despite all the measures adopted or in the case of potential risks, which are not evident, appropriate warnings shall be provided.	Yes	8.3
• The essential characteristics, the recognition and observance of which will ensure that equipment will be used safely and in applications for which it was intended and for which it can reasonably be foreseen, shall be marked legibly and indelibly on the equipment or, if this is not possible, in the accompanying instruction for use.	Yes	7
• Information provided either by marking or in the instructions for use, which is essential for the safe use of the equipment, shall be easily understandable by the intended user.	Yes	7, 8

Bibliography

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~~IEC 60079-20-1, *Explosive atmospheres – Part 20-1: Material characteristics for gas and vapour classification – Test methods and data*~~

~~IEC 60093, *Methods of test for volume resistivity and surface resistivity of solid electrical insulating materials*~~

IEC 60112, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60243 (all parts), *Electric strength of insulating materials – Test methods*

IEC 60695-11-5, *Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*

~~IEC 60812, *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*~~

~~IEC TS 62282-1:2013, *Fuel cell technologies – Part 1: Terminology*~~

IEC 62282-3-100, *Fuel cell technologies – Part 3-100: Stationary fuel cell power systems – Safety*

IEC 62282-5-100, *Fuel cell technologies – Part 5-100: Portable fuel cell power systems – Safety*

IEC Guide 116, *Guidelines for safety related risk assessment and risk reduction for low voltage equipment*

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ISO 16000-6, *Indoor air – Part 6: Determination of ~~volatile~~ organic compounds (VVOC, VOC SVOC) in indoor and test chamber air by active sampling on ~~Tenax TA sorbent, thermal desorption and gas chromatography using MS/FID~~ sorbent tubes, thermal desorption and gas chromatography using MS or MS FID*

ISO 16017-1, *Indoor, ambient and workplace air – Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography – Part 1: Pumped sampling*

ANSI/ASME B31.1, *Power Piping*

ANSI/ASME B31.3, *Process Piping*

ANSI/ASME B31.12, *Hydrogen Piping and Pipelines, Part IP*

ANSI/IAS NGV 4.2, *Hoses for Natural Gas Vehicles and Dispensing Systems*

ANSI/ISA MC96.1, *Thermocouples table in Temperature-Measurement Thermocouples*

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JARI S 003(2018), *Technical Standards for Seamless Containers for Compressed – Hydrogen Vehicle Fuel Device*

NFPA 52, *Compressed Natural Gas (CNG) Vehicular Fuel Systems Code*

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NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases or Vapours and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*

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SAE J2600, *Compressed Hydrogen Surface Vehicle Refuelling Connection Devices*

SAE J2719, *Hydrogen Quality Guideline for Fuel Cell Vehicles*

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UL 429, *Valves, Electrically Operated*

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UL 583, *Industrial Trucks, Electric-Battery-Powered*

UL 698, *Industrial Control Equipment for Use in Hazardous (Classified) Locations*

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UL 840, *Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment*

UL 842, *Valves for Flammable Fluids*

UL 877, *Circuit Breakers and Circuit-Breaker Enclosures for Use in Hazardous (Classified) Locations*

UL 886, *Outlet Boxes and Fittings for Use in Hazardous (Classified) Locations*

UL 969, *Markings and Labeling Systems*

UL 991, *Tests for Safety-Related Controls Employing Solid-State Devices*

UL 1450, *Motor-Operated Air Compressors, Vacuum Pumps, and Painting Equipment*

UL 1642, *Standard for Lithium Batteries*

UL 1004, *Motors, Electric*

UL 1012, *Power Units Other Than Class 2*

UL 1585, *Transformers, Class 2 and Class 3*

UL 1741, *Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources*

UL 1989, *Standard for Standby Batteries*

UL 1998, *Software in Programmable Components*

UL 2054, *Standard for Household and Commercial Batteries*

UL 2075, *Gas and Vapour Detectors and Sensors*

UL 2111, *Motors, Overheating Protection for*

UL 2267, *Fuel Cell Power Systems for Installation in Industrial Electric Trucks*

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IEC 62282-4-101

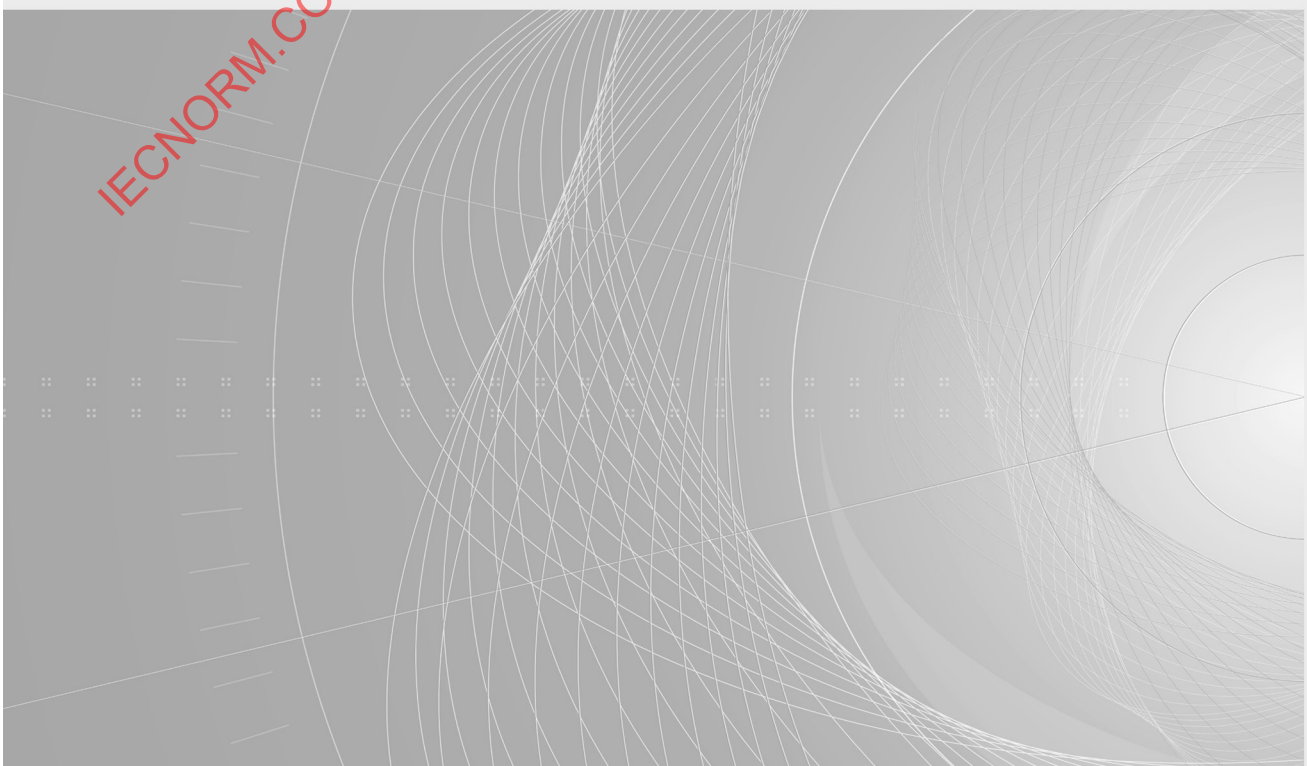
Edition 2.0 2022-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Fuel cell technologies – Part 4-101: Fuel cell power systems for electrically powered industrial trucks – Safety

Technologies des piles à combustible – Partie 4-101: Systèmes à pile à combustible pour chariots de manutention électriques – Sécurité



IEC 62282-4-101:2022-08(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FUEL CELL TECHNOLOGIES –

Part 4-101: Fuel cell power systems for electrically powered industrial trucks – Safety

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 62282-4-101 has been prepared by IEC technical committee 105: Fuel cell technologies.

This second edition cancels and replaces the first edition published in 2014. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) revision of the title of this document;
b) revision of reference standards;
c) addition of new subclauses (4.3, 4.14.5, 4.15.3, 4.15.4, 4.16, 5.6, and 5.23);
d) previous 4.15 was revised as "4.16 Risk assessment and risk reduction";
e) revision of 4.6 3), access to the manual shutoff valve;
f) revision of requirements for battery terminals that are threaded (4.14.10.1);

g) revision of requirements for double layer capacitors (4.14.10.2);

h) revision of external leakage test (5.5) and ultimate strength test (5.7);

i) revision of temperature limits on capacitors depending on the temperature rating of the material (Table 3);

j) revision of markings that are not relevant (Clause 7);

k) added “Significant hazards, hazardous situations and events dealt with in this document” as a new informative annex (Annex B).

The text of this International Standard is based on the following documents:

Draft	Report on voting
105/912/FDIS	105/922/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts of IEC 62282 series, published under the general title *Fuel cell technologies*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

The IEC 62282-4 series deals with categories such as safety, performance and interchangeability of fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU). Among the categories mentioned above, this document, IEC 62282-4-101, focuses on safety of electrically powered industrial trucks with fuel cell power systems because such applications are urgently demanded in the world. Future documents in this part of IEC 62282-4 will deal with other applications related to onboard vehicles other than road vehicles and auxiliary power units (APU).

FUEL CELL TECHNOLOGIES –

Part 4-101: Fuel cell power systems for electrically powered industrial trucks – Safety

1 Scope

This document deals with safety of fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU).

This part of IEC 62282 covers safety requirements for fuel cell power systems intended to be used in electrically powered industrial trucks as defined in ISO 5053-1, except for:

– rough-terrain trucks;
– non-stacking low-lift straddle carriers;
– stacking high-lift straddle carriers;
– rough-terrain variable-reach trucks;
– slewing rough-terrain variable-reach trucks;
– variable-reach container handlers;
– pedestrian propelled trucks.

This document applies to gaseous hydrogen-fuelled fuel cell power systems and direct methanol fuel cell power systems for electrically powered industrial trucks.

The following fuels are considered within the scope of this document:

– gaseous hydrogen;
– methanol.

This document covers the fuel cell power system as defined in 3.8 and Figure 1.

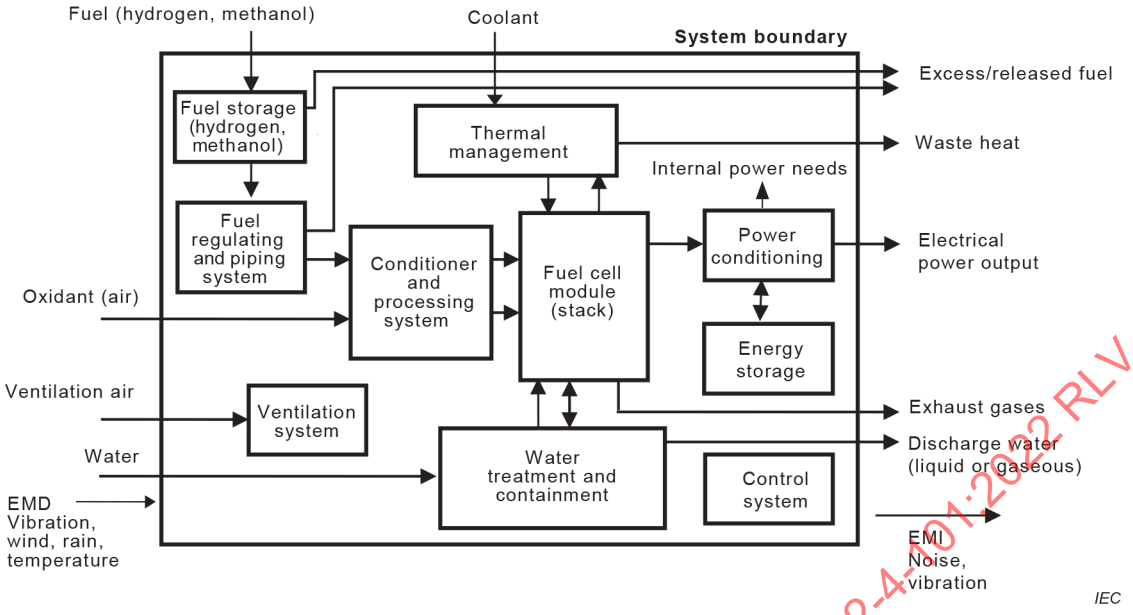
This document applies to DC type fuel cell power systems, with a rated output voltage not exceeding 150 V DC for indoor and outdoor use.

This document covers fuel cell power systems whose fuel source container is permanently attached to either the industrial truck or the fuel cell power system.

In accordance with IEC Guide 116, significant hazards, hazardous situations and events dealt with in this document are shown in Annex B.

The following are not included in the scope of this document:

– detachable type fuel source containers;
– hybrid trucks that include an internal combustion engine;
– reformer-equipped fuel cell power systems;
– fuel cell power systems intended for operation in potentially explosive atmospheres;
– fuel storage systems using liquid hydrogen.



Key

EMD electromagnetic disturbance

EMI electromagnetic interference

NOTE A fuel cell power system can contain all or some of the above components.

Figure 1 – Fuel cell power systems for industrial trucks

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-485, *International Electrotechnical Vocabulary (IEV) – Part 485: Fuel cell technologies*

IEC 60079-0, *Explosive atmospheres – Part 0: Equipment – General requirements*

IEC 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

IEC 60079-29-1, *Explosive atmospheres – Part 29-1: Gas detectors – Performance requirements of detectors for flammable gases*

IEC 60079-29-4, *Explosive atmospheres – Part 29-4: Gas detectors – Performance requirements of open path detectors for flammable gases*

IEC 60204-1, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60227-3, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 3: Non-sheathed cables for fixed wiring*

IEC 60227-5, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 5: Flexible cables (cords)*

IEC 60335-2-41, *Household and similar electrical appliances – Safety – Part 2-41: Particular requirements for pumps*

IEC 60335-2-80, *Household and similar electrical appliances – Safety – Part 2-80: Particular requirements for fans*

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric* shock
IEC 60364-4-41:2005/AMD1:2017

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60584-1, *Thermocouples – Part 1: EMF specifications and tolerances*

IEC 60664-1, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60695 (all parts), *Fire hazard testing*

IEC 60695-1-30, *Fire hazard testing – Part 1-30: Guidance for assessing the fire hazard of electrotechnical products – Preselection testing process – General guidelines*

IEC 60695-10-2, *Fire hazard testing – Part 10-2: Abnormal heat – Ball pressure test method*

IEC 60695-11-4, *Fire hazard testing – Part 11-4: Test flames – 50 W flame – Apparatus and confirmational test method*

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IEC 60730-1:2013/AMD1:2015
IEC 60730-1:2013/AMD2:2020

IEC 60812, *Failure modes and effects analysis (FMEA and FMECA)*

IEC 60947-3, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

IEC 60947-5-1, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

IEC 60950-1:2005, *Information technology equipment – Safety – Part 1: General requirements*
IEC 60950-1:2005/AMD1:2009
IEC 60950-1:2005/AMD2:2013

IEC 61025, *Fault tree analysis (FTA)*

IEC 61204-7, *Low-voltage switch mode power supplies – Part 7: Safety requirements*

IEC TS 61430, *Secondary cells and batteries – Test methods for checking the performance of devices designed for reducing explosion hazards – Lead-acid starter batteries*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61558-1, *Safety of transformers, reactors, power supply units and combinations thereof – Part 1: General requirements and tests*

IEC 62477-1, *Safety requirements for power electronic converter systems and equipment – Part 1: General*

IEC 62133-1, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications – Part 1: Nickel systems*

IEC 62282-2-100, *Fuel cell technologies – Part 2-100: Fuel cell modules – Safety*

IEC 62391-1, *Fixed electric double-layer capacitors for use in electric and electronic equipment – Part 1: Generic specification*

IEC 62391-2, *Fixed electric double-layer capacitors for use in electronic equipment – Part 2: Sectional specfication – Electric double layer capacitors for power application*

IEC 62619, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries, for use in industrial applications*

IEC/ISO 31010, *Risk management – Risk assessment techniques*

ISO 179 (all parts), *Plastics – Determination of Charpy impact properties*

ISO 180, *Plastics – Determination of Izod impact strength*

ISO 877 (all parts), *Plastics – Methods of exposure to solar radiation*

ISO 1419, *Rubber- or plastics-coated fabrics – Accelerated-ageing tests*

ISO 1421, *Rubber- or plastics-coated fabrics – Determination of tensile strength and elongation at break*

ISO 1798, *Flexible cellular polymeric materials – Determination of tensile strength and elongation at break*

ISO 2440, *Flexible and rigid cellular polymeric materials – Accelerated ageing tests*

ISO 2626, *Copper – Hydrogen embrittlement test*

ISO 3691-1, *Industrial trucks – Safety requirements and verification – Part 1: Self-propelled industrial trucks, other than driverless trucks, variable-reach trucks and burden-carrier trucks*

ISO/TS 3691-7, *Industrial trucks – Safety requirements and verification – Part 7: Regional requirements for countries within the European Community*

ISO/TS 3691-8, *Industrial trucks – Safety requirements and verification – Part 8: Regional requirements for countries outside the European Community*

ISO 3864-1, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs and safety markings*

ISO 4038, *Road vehicles – Hydraulic braking systems – Simple flare pipes, tapped holes, male fittings and hose end fittings*

ISO 4080, *Rubber and plastics hoses and hose assemblies – Determination of permeability to gas*

ISO 4675, *Rubber- or plastics-coated fabrics – Low-temperature bend test*

ISO 5053-1, *Industrial trucks – Vocabulary – Part 1: Types of industrial trucks*

ISO 7010, *Graphical symbols – Safety colours and safety signs – Registered safety signs*

ISO 10380, *Pipework – Corrugated metal hoses and hose assemblies*

ISO 10442, *Petroleum, chemical and gas service industries – Packaged, integrally geared centrifugal air compressors*

ISO 10806, *Pipework – Fittings for corrugated metal hoses*

ISO 11114-4, *Transportable gas cylinders – Compatibility of cylinder and valve materials with gas contents – Part 4: Test methods for selecting metallic materials resistant to hydrogen embrittlement*

ISO 12100, *Safety of machinery – General principles for design – Risk assessment and risk reduction*

ISO 13226, *Rubber – Standard reference elastomers (SREs) for characterizing the effect of liquids on vulcanized rubbers*

ISO 13849-1, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

ISO 13849-2, *Safety of machinery – Safety-related parts of control systems – Part 2: Validation*

ISO 14113, *Gas welding equipment – Rubber and plastics hose and hose assemblies for use with industrial gases up to 450 bar (45 MPa)*

ISO 15649, *Petroleum and natural gas industries – Piping*

ISO/TR 15916, *Basic considerations for the safety of hydrogen systems*

ISO 16010, *Elastomeric seals – Material requirements for seals used in pipes and fittings carrying gaseous fuels and hydrocarbon fluids*

ISO 16111:2018, *Transportable gas storage devices – Hydrogen absorbed in reversible metal hydride*

ISO 17268, *Gaseous hydrogen land vehicle refuelling connection devices*

ISO 19881, *Gaseous hydrogen – Land vehicle fuel containers*

ISO 19882, *Gaseous hydrogen – Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers*

ISO 20898, *Industrial trucks – Electrical requirements*

ISO 21927-3, *Smoke and heat control systems – Part 3: Specifications for powered smoke and heat exhaust ventilators*

ISO 23551-1, *Safety and control devices for gas burners and gas-burning appliances – Particular requirements – Part 1: Automatic and semi-automatic valves*

UN GTR No. 13, *Global Technical Regulation concerning the hydrogen and fuel cell vehicles*

UN Regulation No. 134, *Uniform provisions concerning the approval of motor vehicles and their components with regard to the safety- related performance of hydrogen-fuelled vehicles (HFCV)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-485 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
abnormal operation
operation of the fuel cell power system with any one mechanical, electrical or control component malfunction or failure, in any failure mode regarded as reasonably probable in the failure mode and effects analysis (FMEA) but excluding accidental rupture or breakdown of the containers of flammable liquids, and/or gases

3.2
equipotential bonding
permanent joining of conductive parts to form a positive electrically conductive path that provides electrical continuity between non-current carrying conductive parts and is capable of conducting any fault current that can occur

Note 1 to entry: This applies to bonding within the fuel cell system and between the fuel cell system and truck and does not refer to the means to earth the truck itself, such as with an earthing strap or with tires.

3.3
check-valve
fluid control device that allows fluids to flow in only one direction

3.4
limited power circuit
circuit involving a potential greater than 42,4 V peak (30 V RMS) or 60 V DC and whose power after 60 s of operation complies with the values outlined in Table 2B and Table 2C of IEC 60950-1:2005 and IEC 60950-1:2005/AMD2:2013

Note 1 to entry: A circuit that is low voltage under both normal and single fault conditions is referred to in IEC 60950-1 as a safety extra low voltage (SELV).

3.5
low-voltage circuit
circuit involving a peak open-circuit potential of not more than 42,4 V (30 V RMS) or 60 V DC supplied by a battery, a fuel cell, a transformer having a rated power output rating of less than 100 VA and a maximum secondary output of 30 V AC or by a combination of a transformer and a fixed impedance that, as a system, complies with IEC 61558-1

Note 1 to entry: A circuit derived by connecting a resistance in series with a voltage supply circuit as a means of limiting the voltage and current is not considered to be a low-voltage circuit.

3.6
dilution boundary
extent of a flammable area or zone created by a limited release of flammable gas, internal to the fuel cell power system or truck in which it is mounted, and controlled by mechanical ventilation or other effective means

Note 1 to entry: This is outlined in IEC 60079-10-1.

3.7
electrostatic discharge
ESD
transfer of electric charge between bodies of different electrostatic potentials in proximity or through direct contact

[SOURCE: IEC 60050-561:2014, 561-03-06]

3.8
fuel cell power system
generator system that uses one or more fuel cell modules to generate electric power and heat

Note 1 to entry: See Figure 1 for a block diagram of a fuel cell power system. The fuel cell power system for use with industrial trucks will be in one of the forms as outlined in 3.9 and 3.10.

[SOURCE: IEC 60050-485:2020, 485-09-01, modified – addition of the Note to entry.]

3.9
self-contained system
complete system incorporated into its own housing that is intended to replace or combine with a battery system to power an industrial truck

Note 1 to entry: Display and control functions can be located outside the system's housing in proximity to the operator's compartment. However, if counterweight is required outside the system's housing or direct communication is required between the system and the truck controller, then it will be considered an integrated system (see 3.10).

3.10
integrated fuel cell power system
complete system of fuel cell components and parts that are incorporated into the industrial truck with the various parts of the system potentially distributed throughout the truck

3.11
hazardous zone
any work area or space where combustible dust, ignitable fibres, or flammable, volatile liquids, gases, or mixtures are or can be present in the air in quantities sufficient to produce explosive or ignitable mixtures as defined by IEC 60079-10-1

3.12
integral
something that is either contained within the fuel cell power system or is external to it, but is a part of the fuel cell power system

3.13
lower flammability limit
LFL
minimum concentration of fuel in a fuel-air mixture where a combustion can be ignited by an ignition source

Note 1 to entry: A fuel-air mixture is flammable when combustion can be started by an ignition source. The main component concerns the proportions or composition of the fuel-air mixture. A mixture that has less than a critical amount of fuel, known as the lower flammability limit (LFL) or more than a critical amount of fuel, known as the rich or upper flammability limit (UFL), will not be flammable.

3.14
maximum allowable working pressure
MAWP
maximum gauge pressure at which a fuel cell or fuel cell power system can be operated

Note 1 to entry: See Annex A for a comparison table of pressure terms.

Note 2 to entry: The maximum allowable working pressure is expressed in Pa.

Note 3 to entry: The maximum allowable working pressure is the pressure used in determining the setting of pressure limiting/relieving devices installed to protect a component or system from accidental over-pressuring.

[SOURCE: IEC 60050-485:2020, 485-17-03, modified – addition of new Note 1 to entry.]

3.15
maximum operating pressure
MOP
highest gauge pressure of a component or the system that is expected during normal operation

Note 1 to entry: See Annex A for a comparison table of pressure terms.

3.16
normal release
limited localized volumes of hydrogen concentrations released during normal operation that can include fuel cell purge

3.17
normal operation
all operating and non-operating modes encountered during product use that are not the result of a malfunction or failure

3.18
pressure relief device
PRD
pressure and/or temperature activated device used to prevent the pressure from rising above a predetermined maximum and thereby prevent failure of a pressurized part or system

3.19
thermally activated pressure relief device
TPRD
pressure relief device (3.18) activated by temperature

3.20
risk assessment
overall process comprising a risk analysis and a risk evaluation

3.21
risk analysis
systemic use of available information to identify hazards and to estimate the risk

3.22
risk evaluation
procedure based on the risk analysis to determine whether a tolerable risk has been achieved

3.23
safety control
automatic controls and interlocks including relays, switches, sensors and other auxiliary equipment used in conjunction therewith to form a safety control system, which is intended to prevent unsafe operation of the controlled equipment

3.24
safety critical component
component, device, circuit, software or similar part whose failure would affect the safety of the fuel cell power system as determined in 4.16

3.25
service pressure
nominal working pressure
pressure, as specified by the manufacturer, at a uniform gas temperature of 15 °C and with full gas content

Note 1 to entry: This term only relates to the hydrogen pressure vessel.

Note 2 to entry: See Annex A for a comparison table of pressure terms.

3.26
zone system of classification
means for classifying areas within the fuel cell power system using the methods outlined in IEC 60079-10-1

4 Construction requirements for safety

4.1 General

Any component of a product covered by this document shall comply with the requirements for that component. Normative references for standards covering components used in the products covered by this document are given in Clause 2.

A component is not required to comply with a specific requirement of the normatively referenced standards that:

– involves a feature or characteristic not required in the application of the component in the product covered by this document;
– is superseded by a requirement in this document, or
– is separately investigated when forming part of another component, provided the component is used within its established ratings and limitations.

Any component shall be used in accordance with its rating established for the intended conditions of use.

Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

A component that is also intended to perform other functions such as overcurrent protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any combination thereof, shall additionally comply with the requirements of the applicable standard that covers devices that provide those functions.

4.2 Hydrogen and other fluid containing parts

4.2.1 General

Pressure or fluid containing parts shall be resistant to the action of the fluid.

Metallic parts containing hydrogen gas shall be resistant to hydrogen embrittlement as outlined in ISO/TR 15916. If employing a material other than as outlined in ISO/TR 15916, an evaluation for susceptibility to hydrogen embrittlement will need to be conducted in accordance with ISO 11114-4 or ISO 2626.

Where atmospheric corrosion of a part containing fluid interferes with its intended function, or permits external leakage of a fluid creating a hazardous condition, the part shall be made of corrosion-resistant material or is to be provided with a corrosion-resistant protective coating.

Any elastomeric parts, relied upon for safety such as a seal for fluids other than hydrogen, which could create a hazard when leaked (for example, a gasket between electrical and wetted parts), shall be suitable for the application as determined by ISO 1419, ISO 1421, ISO 13226, ISO 16010 and ISO 4675, as applicable.

Any elastomeric parts employed as a seal for hydrogen shall be suitable for use with hydrogen. The elastomeric materials outlined in ISO/TR 15916 shall be considered for reference and guidance. The material shall be evaluated for tensile strength and elongation as-received and after oven-ageing (based on service temperatures) in accordance with 5.20.

4.2.2 Piping, hoses, tubing and fittings

1) Where conveying gases at gauge pressures exceeding 103,4 kPa, liquids at pressures exceeding 1 103 kPa, or temperatures exceeding 120 °C, piping and associated component parts shall be designed, fabricated and tested to conform to all applicable specifications of ISO 15649.
2) Piping utilized at levels below the pressures and/or temperatures noted in 1) and nonmetallic piping shall be evaluated to the requirements of this document with consideration given to materials and fluids contained and service conditions, including pressures and temperatures. Non-metallic piping containing gaseous hydrogen or methanol fuel shall be designed, fabricated and tested to the additional requirements in 6).
3) Non-metallic hoses used for gaseous hydrogen or methanol fuels located outside the fuel cell power system and subject to physical stress shall meet the hydrostatic testing, adhesion (rubber only), flexibility, low-temperature flexibility, ozone resistance (for hoses with an outer protective cover of rubber), UV resistance (for hoses with plastic cover), permeability to gas, electrical conductivity, and end fitting integrity tests of ISO 14113. Materials shall be suitable for service with hydrogen fuel, or the fluid contained (i.e. methanol), in accordance with 4.21. Flexible hoses longer than 1,5 m shall have a stainless-steel wire braid reinforcement.
4) Flexible metal connectors and associated fittings, when used for conveying gaseous hydrogen, shall comply with ISO 10806 and ISO 10380, as required.
5) A hydrogen fuel line shall be supported to minimize chafing and to maintain at least a 51 mm clearance from exhaust- and electrical-system parts.
    a) Electrical equipment and sensors in limited power circuits that do not have enough electrical energy to damage a fuel line are not required to comply with this requirement.
    b) If it can be demonstrated that the fuel lines and wiring are sufficiently supported to prevent the clearance from being reduced to less than 12,7 mm, the clearance between fuel lines and electrical-system parts can be reduced.

6) Non-metallic hydrogen and methanol fuel lines shall:
   - be protected within ventilated enclosures where they will be subject to a minimum of mechanical or physical stresses;
   - be conductive to avoid static discharge. Compliance is determined by the continuity test of 5.10 2) for metal fuel lines, and of 5.10 3), for nonmetallic fuel lines;
   - employ materials that have been evaluated and found suitable for the fluids they contain with consideration given to temperatures they are exposed to during service. Compliance shall be determined by 5.20 and 5.21, as applicable; and
   - comply with the ESD requirements for ISO 4038 when connected between the fuel system and the stack.
7) Pipe, tubing, fittings, and other piping components shall be capable of withstanding a minimum hydrostatic test of 1,5 times the rated service pressure without structural failure. High-pressure pipe, tubing, fittings, and other piping components shall have a safety margin equivalent to the storage cylinder in use. See 4.2.3.

4.2.3 Hydrogen pressure vessels

1) Pressure vessels shall be specifically designed for the service conditions of the industrial truck application that include the maximum number of fill cycles expected, the ranges of pressures and temperatures expected during operation and filling, the effect of hydrogen on fatigue life and the frequency of inspection.
2) With reference to 1), a pressure vessel shall be designed, manufactured, and tested with the following conditions and limitations:
   a) container Category C defined in ISO 19881 shall apply;
   b) for Type 1 vessels, the vessel shall be designed and tested in accordance with ISO 19881;
   c) the term "working pressure" of the vessel as defined in ISO 19881 is identical to "service pressure" in this document;
   d) for Type 3 and Type 4 vessels, the vessel shall be designed and tested in accordance with ISO 19881, UN GTR No.13 and UN Regulation No. 134;
   e) the vessel shall be designed for the excepted life of the fuel cell power system and not fewer than 11 250 full fill cycles.

   NOTE "11 250 full fill cycles", for example, 3 refills/day, 365 days/years, 10 years = 10 950 cycles.
3) A pressure vessel and fill fitting shall be placed within the plan view outline of the industrial truck or placed in an enclosure as defined in 4.13 and located to minimize the possibility of damage to the vessel or hydrogen-related fittings.
4) An excess-flow and check-valve, if present, shall be directly connected to the pressure vessel or mounted in line with the pressure vessel, where there is no shut-off device in between the pressure vessel and the check valve, so as to minimize the negative effects of shock, vibration and accidental damage.
5) The refuelling line shall be fitted with a redundant check valve for the check valve in the receptacle specified in ISO 17268.
6) Pressure vessels shall have a provision for being de-fuelled (de-pressurized) and purged of hydrogen using an inert gas as outlined in the operating instructions or the maintenance manual, as applicable, provided with the fuel cell power system.
7) A manual valve to isolate the fuel supply shall be located near the pressure vessel so that the fuel supply to the fuel power system can be shut off for maintenance or long-term storage.
8) The hydrogen pressure vessel shall be permanently mounted to the fuel cell power system module or to the industrial truck to ensure the pressure vessel does not become dislodged while in use and is not removable for refuelling.

4.2.4 Metal hydride container

Fuel storage systems using hydrogen stored in metal hydrides shall comply with Clause 4, Clause 5, and Clause 6 of ISO 16111:2018.

4.2.5 Methanol fuel tank

1) Methanol fuel vessels shall be constructed of suitable materials in accordance with 4.2.1 and 4.2.2 and shall meet the requirements as noted below. Such vessels, and their related joints and fittings, shall be designed and constructed with adequate strength for functionality and leakage resistance to prevent unintended releases.
2) Methanol fuel vessels shall be specifically designed for the service conditions of the industrial truck application that includes the ranges of pressures and temperatures expected during operation and filling, the effect of methanol on fatigue life of the tank, and the frequency of inspection.
3) A manual valve to isolate the fuel supply shall be located near the fuel tank so that the fuel supply to the fuel cell power system can be shut off for maintenance or long term storage.
4) A methanol fuel vessel and fill fitting shall be placed within the truck envelope or placed in an enclosure as defined in 4.13, and located to minimize the possibility of damage to the vessel or fittings.
5) The methanol fuel tank shall be permanently mounted to the fuel cell power system module or to the industrial truck to ensure the tank does not become dislodged while in use and is not removable for refuelling.

4.3 Refueling

The refueling interface shall correspond to the container pressure rating (see 4.2.3 2)c)) and shall be in accordance with ISO 17268.

4.4 Over-pressure and thermal protection

1) The hydrogen pressure vessel shall be protected from the effects of fire by a nonreclosing thermally activated pressure relief device (TPRD) that is designed, manufactured and tested in accordance with ISO 19882.
2) Components and piping located downstream of a pressure reducing valve that are rated to a pressure that is lower than the maximum inlet pressure of the pressure reducing valve shall be protected from over-pressure in the event of a failure of the pressure reducing valve by way of a pressure relief device.
3) Pressure relief devices shall be suitable for their application, including materials in contact with hydrogen and pressure and flow ratings.
4) Pressure relief devices operating at over 1 000 kPa shall be sized and designed to limit the pressure during a fault to less than 110 % of the maximum allowable working pressure. Re-closure shall occur at no less than 90 % of the set point. Pressure relief devices operating at or below 1 000 kPa shall be sized and designed to limit the pressure during a fault to less than 125 % of the maximum allowable working pressure. Re-closure shall occur at no less than 90 % of the set point. Fuel cell stack shall be protected in accordance with IEC 62282-2-100.
5) When provided, pressure relief discharge piping shall be sized to ensure compliance with 4.4 4).
6) A pressure relief device shall have its discharge located so that operation of the named device does not result in a hazardous situation such as:
   a) hydrogen gas in excess of 25 % of the lower flammability limit (LFL) escaping to an unclassified or pressure-confined area within the fuel cell power system. The discharge of the pressure relief device can be located within the fuel cell power system by using an adequate ventilation or implementing an adequate safety-controlled system composed of a hydrogen sensor and a hydrogen shut-off valve plugging the leak in case of detection;
   b) deposition of moisture on live parts that could create a risk of electric shock;

c) possible access of foreign objects, moisture or debris to enter the venting system not protected by caps, covers or other means;

d) chance for the venting system to become unsecured or removed such that it would affect the intended flow path, or

e) the pressure release being directed towards or impinged towards the normal operator position.

7) A pressure relief device vent shall be secured at intervals in such a manner as to minimize the possibility of damage, corrosion, or breakage of either the vent line or the pressure relief device due to expansion, contraction, vibration, strains, or wear and to preclude any loosening while in operation.

8) The vent system including the outlet connection of the relief device and associated vent lines shall be designed to withstand the maximum pressure developed during full flow operation of the relief device without becoming detached from its securement. If provided, the vent cap shall be secured for the safety.

9) Pressure relief devices, as shown in the examples in Figure 2, Figure 3, and Figure 4, shall be in accordance with ISO 15649.

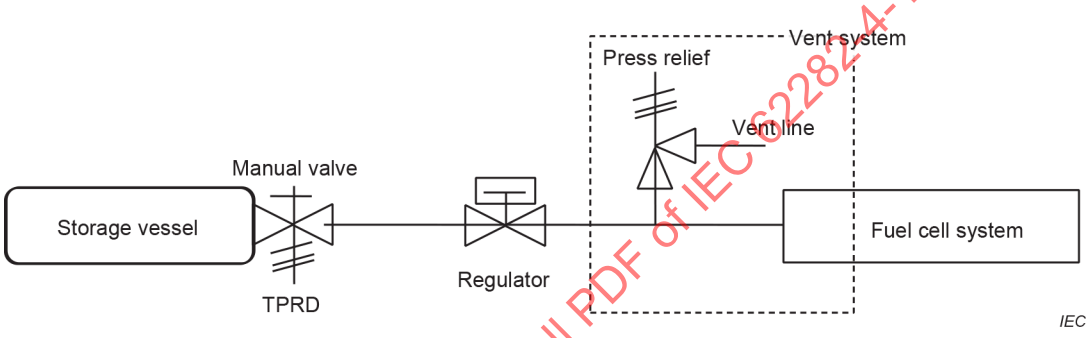

Figure 2 – Example of a diagram with vent system covering components downstream of the regulator

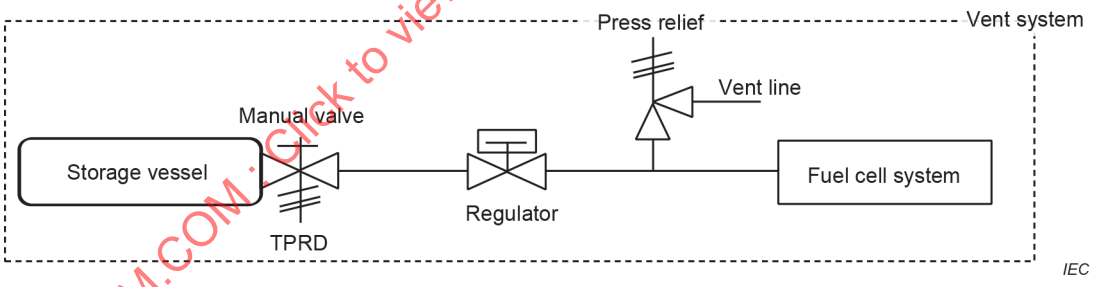

Figure 3 – Example of a diagram with vent system covering all components

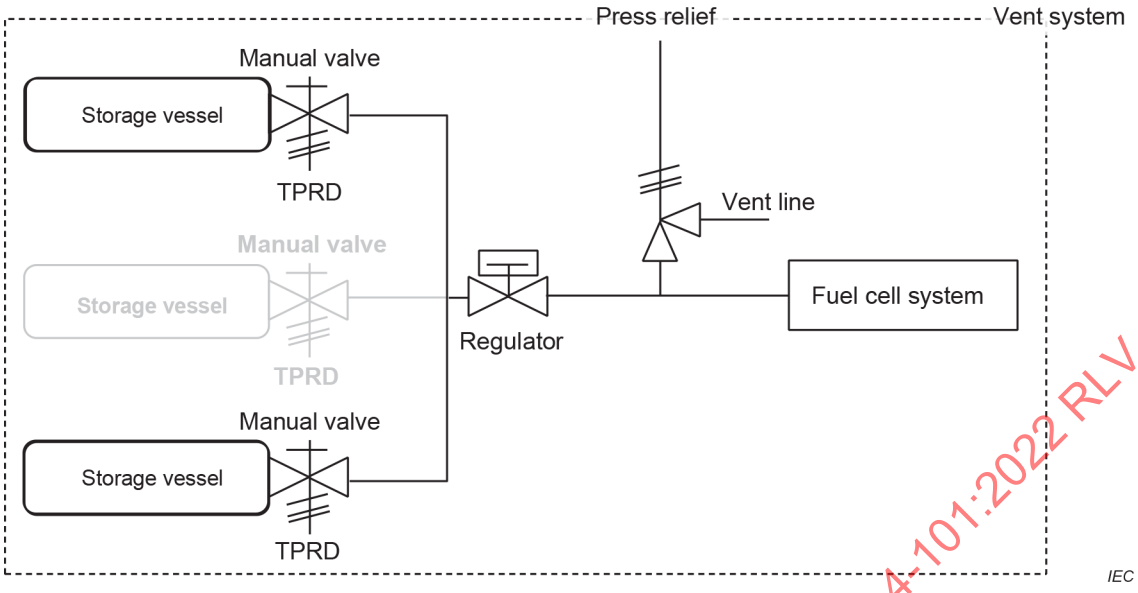

Figure 4 – Example of a diagram with vent system covering all components in a multiple storage vessel system

4.5 Regulators

The gas pressure regulator shall be equipped with a vent limiter or a vent line.

4.6 Operating and shut-off valves

1) Valves shall be rated for the application, including pressure, temperature, fluids contacted, and electrical ratings, if applicable.
   a) Electrically operated valves shall comply with ISO 23551-1.
   b) Valves for high pressure piping shall be tested in accordance with ISO 15649, instead of the external leakage test and the hydrostatic strength test of ISO 23551-1.
   c) Valves for flammable fluids shall comply with ISO 23551-1.
2) Fuels supplied to the fuel cell power system shall be supplied through fuel lines provided with at least one automatic safety shut-off valve. The safety shut-off valve can also be an operating valve. The closing time for a safety shut-off valve shall be no greater than 5 s.
3) If an emergency manual shut-off valve is deemed necessary according to 4.16, it shall be in a readily accessible location and shall not have more than 90° rotation from the open to the closed positions. Any key or tool shall not prevent access to the manual shutoff valve. The valve shall be securely mounted and shielded or installed in a protected location to minimize damage from vibration or collision.
4) Where a manual valve is used, the valve shall be indicated with a marking in accordance with Clause 7 3)f).
5) Electrical and other automatically operated safety shut-off valves shall fail in a safe position.
6) Electrical valves located in classified areas shall be rated for the area of classification.

4.7 Filters

Air and fluid filters shall be suitable for the application and readily accessible if required to be inspected, cleaned, or replaced.

4.8 Pumps and compressors

1) Air compressors and air vacuum pumps employed in the system shall comply with ISO 10442.
2) Water pumps shall comply with IEC 60335-2-41.

3) Chemical and gaseous hydrogen pumps and compressors shall be evaluated to the applicable material compatibility requirements, mechanical and electrical requirements of this document.

4) A flammable fluid compressor or pump with rotating or other type dynamic seals, shall be provided with adequate ventilation so that small releases of hydrogen under normal operating conditions shall not allow the concentration of hydrogen to be above 25 % of the lower flammability limit (LFL) in the unclassified areas of the fuel cell power system during normal release.

4.9 Electrically operated pressure sensing and controlling devices

1) Pressure activated switches and transducers shall be rated for the application. A pressure regulating control for a flammable or combustible fluid shall be suitable for its classification and the fluid it contains.

2) The maximum operating pressure of a pressure limiting or regulating control shall not exceed 90 % of the operating pressure of a pressure relief device. An accessible and adjustable pressure regulating control that can exceed the limits of the system shall be reliably sealed at the maximum operating pressure at which it is intended to operate.

4.10 Ventilation to prevent the build up of flammable gases

1) A fuel cell power system shall be provided with adequate ventilation so that normal releases under normal operating conditions shall not allow the concentration of hydrogen to be above 25 % of the lower flammability limit (LFL) in the unclassified zones of the fuel cell power system. This normal release shall include nominal stack fuel leakage rates or fuel purges that can occur during operation.

2) The diluted concentrations of hydrogen exiting the fuel cell power system even during abnormal operation shall not exceed 25 % of the lower flammability limit (LFL).

NOTE See IEC 62282-3-100 or IEC 62282-5-100.

3) The extent of a flammable region at a source of limited release (dilution boundary) shall be determined through appropriate analysis as outlined in IEC 60079-10-1.

4) Equipment located within the dilution boundary shall be suitable for the classification. Reference can be made to IEC 60079-0.

5) Abnormal releases of flammable fluids shall not create a safety hazard in accordance with 4.16, and shall result in the appropriate action, including the prompt shut down of the equipment, if necessary, that will mitigate the hazard or prevent the creation of additional hazards.

6) Mechanical ventilation shall be provided to keep the dilution boundary of 25 % lower flammability limit (LFL), under conditions of normal release, away from the unclassified components. Failure of ventilation shall cause the fuel cell power system to respond in such a way that shall mitigate any hazard or prevent the creation of additional hazards in accordance with 4.16. This can include shutting off, either through the detection of high gas concentration or with ventilation interlock provisions.

   a) Limited, localized volumes of hydrogen concentration within the fuel cell power system can momentarily exceed the 25 % LFL of the hydrogen, but it shall be determined, in accordance with 4.16, that this transient condition does not create a safety hazard.

   b) Mechanical ventilation is not required if it can be determined that the flammable gas concentration level falls below 25 % LFL under any conditions of normal release.

7) If gas detection is employed as a critical safety component in the fuel cell power system, the gas detection system shall comply with IEC 60079-29-1 and IEC 60079-29-4. Gas detection systems shall be located where they can most effectively measure the accumulation of hydrogen within the fuel cell power system and monitor the ventilation output as determined necessary.

8) If gas detection is employed as a critical safety component in the fuel cell power system, it shall be located in a control circuit that complies with IEC 60730-1:2013, IEC 60730-1:2013/AMD1:2015 and IEC 60730-1:2013/AMD2:2020, Annex H, and in accordance with 4.15.1 of this document.

9) In case of hydrogen leakage, the shut down valve shall be automatically operated. Similarly, the electrical switch shall be automatically shut down. The safety hydrogen sensor shall remain operational provided this does not increase the risk. In case of hydrogen safety sensor failure, the shut down valve shall be automatically operated. Similarly, the electrical switch shall be automatically shut down. Considering battery and tank safety testing, the appropriate documents such as IEC 62619 should be applied.

10) Ventilation openings and ducts shall not become obstructed or compromised when the fuel cell power system is normally operated in the truck.

11) Fans, blowers, and other devices employed for the ventilation system shall be suitable for the application. If fans and ventilators are used as the primary safety mechanism to prevent the build-up of flammable gas, the failure of the ventilation system shall not create a safety hazard in accordance with 4.16. Fans shall comply with IEC 60335-2-80. Ventilators shall comply with ISO 21927-3.

4.11 Electrostatic discharge (ESD)

1) Hydrogen fuel containing parts and parts within classified zones (see 3.26) of the equipment shall be constructed of materials that do not promote static discharges.

2) The exposed portion of moving metal parts such as fan blades and wheels, located in classified areas of the system shall be made of, or covered with, medium brass, bronze, copper or aluminum with hardness not more than Rockwell B66. Energy storage components such as batteries or ultracapacitors, and major power electronics components, such as fuel cell stack module, shall have their external conductive cases equipotentially bonded.

3) Components with non-current carrying metal parts and cases located in classified zones within the equipment shall be equipotentially bonded.

4) When a self-contained fuel cell power system is installed in a truck, a conductive path shall be provided between the fuel cell equipment components requiring equipotential bonding and the chassis of the truck.

5) Any fuel receptacle on the fuel cell power system provided for refuelling shall be equipotentially bonded to the fuel cell power system chassis.

6) Markings and instructions regarding the hazard involved with the buildup of static discharge and the means to mitigate this hazard shall be in accordance with Clause 7 3)d) and 8.4 2).

4.12 Discharges including methanol emissions and waste materials

1) The fuel cell power system shall be constructed so that waste materials, including water, are not exhausted, discharged or leaked in a manner that could create unsafe conditions.

2) Emissions from methanol fueled fuel cell power systems shall not exceed safe limits. Compliance is determined by the emission of effluents test of 5.16. Systems shall be designed to prevent emissions from entering the passenger compartment of the end use industrial truck application.

4.13 Enclosures

1) A fuel cell power system shall be enclosed for protection from access by persons to electrical parts, safety circuits, hazardous moving parts, hot surfaces, and other parts that can be a risk of injury.

2) Openings in a fuel cell power system enclosure of hazardous parts shall be located and sized to provide adequate protection from access to hazardous parts complying with a minimum IPXXB or IP2X minimum rating as outlined in IEC 60529.

3) An external enclosure for a fuel cell power system provided with an IP rating in accordance with Clause 7 2)j) shall comply with the rain test in 5.17.1.

4) An external enclosure shall comply with the test of 5.18.1, unless the required protection is provided by the truck for an integrated fuel cell power system.

5) Non-metallic enclosure materials shall be flame rated V-1 minimum in accordance with IEC 60695-11-10 or shall comply with the test for thermoplastic materials in 5.19.

6) Any thermoplastic enclosure of a fuel cell power system shall be suitable for the range of temperatures that it is subjected to during use.

7) The system enclosure shall be designed to prevent the accumulation of liquids inside the enclosure. Drains are one potential means for compliance.

4.14 Electrical system

4.14.1 General

1) Electrical components shall be rated for the application and conform to the appropriate document for those components. They shall be located and secured so that they are not adversely affected by vibration, temperature, environment and other effects during normal operation of the fuel cell power system.
2) If electrical equipment internal to the fuel cell power system is located in hazardous zones, it shall be identified and managed according to IEC 60079-0.
3) EMC is subject to regional requirements. See ISO/TS 3691-7 and ISO/TS 3691-8.

4.14.2 Internal wiring

1) Internal wiring shall consist of any of the following:
   a) general-use wire specified in IEC 60364;
   b) appliance-wiring material of one or more of the types specified in Table 1.
2) The wiring shall be considered with respect to the temperature and conditions of service to which the wiring is to be subjected in the end truck installation.
3) At the connection to a component, wiring is permitted to extend beyond the braid for a length of no more than 254 mm.
4) Appliance-wiring material having a thickness of insulation less than the minimum acceptable value specified in Table 1 is permitted for a particular application, provided the insulation is considered with respect to temperature and conditions of service and is equivalent to one of the materials specified in Table 1.
5) A bare conductor is permitted to be insulated with insulating tubing.
6) Wiring shall be protected against mechanical damage by:
   – enclosing it within the fuel cell power system enclosure for self-contained fuel cell power systems, and
   – enclosing it within the body of the truck for integrated fuel cell power systems.
7) A conductor connected to a moving or movable part that cannot be protected, shall be designed for the intended use and shall comply with the test requirements in this document. Consideration shall be given to the resistance of the conductor to damage resulting from flexing, abrasion, or impact. Flexible metallic conduit is to be used only for flexible connections subject to small and infrequent movements.
8) Wiring connections to a continuously moving part, or a part for which the degree of movement is appreciable, shall be in accordance with IEC 60227-5.
9) The tubing can be omitted from exposed moving conductors that are readily visible to the operator and are, therefore, subject to replacement when damaged. The maintenance manual shall include instructions regarding inspection of these conductors for replacement when damage occurs in accordance with 8.2 5).
10) All of the connections shall be mechanically secure and shall provide electrical contact without stress on connections and terminals. A connection shall be provided with insulation equivalent to that on the wires involved.
11) A hole, through which insulated conductors pass, shall be provided with a smooth, rounded bushing, or shall have smooth, rounded surfaces upon which the insulated conductors may bear.
12) Wireways shall be smooth and free from sharp edges, burrs, fins, or moving parts that can damage wiring.
13) An internal-wiring connection shall be made with a solder lug or pressure terminal connector.

14) Control wiring and other small conductors, which are connected by crimped or soldered special-type lugs or eyelets including barrel terminals or by ultrasonic welding and that are insulated in accordance with 7), comply with the intent of this requirement.

15) A terminal lug shall be arranged so that in any position it cannot contact either the metal enclosure and non-energized accessible metal parts or other electrical circuits, or the shank of the lug shall be provided with insulation equivalent to that on the conductor.

Table 1 – Appliance-wiring material

Wire insulation	Minimum acceptable average insulation thickness mm
Rubber, neoprene or thermoplastic (PVC)	0,38 plus an impregnated braid, or 0,75 without a braid

4.14.3 External wiring

1) An external electrical output lead shall be of a size and capacity such that for a rated power output, the insulation temperature does not exceed its rating at maximum ambient temperature. It shall be provided with insulation able to withstand flexing, handling, and impact at temperatures between 50 °C and –20 °C. If intended for exposure to extreme temperatures above 50 °C and at or below –20 °C, the lead shall comply with 5.22. The average insulation thickness shall be fixed in accordance with IEC 60227-3. The length of the lead and connector assembly shall be as short as practicable without interfering with the disconnecting operation and without placing stress on terminals when installed in the truck.

2) An external electrical output connector shall be rated for the output of the fuel cell power system. Live parts shall be recessed from the face of the connector to reduce the possibility of shorting. A removable portion of the connector shall be provided with means for being grasped during removal. The connector shall be located to provide mechanical protection when the fuel cell power system is installed in the end use.

3) External wiring shall be protected against mechanical damage by

   a) enclosing it in the body of the truck,

   b) enclosing it in a metal raceway such as armored cable, rigid metal conduit or electrical metallic tubing, or

   c) protecting it with metal, phenolic composition, or other thermosetting material having equivalent mechanical strength and resistance to impact and having no greater combustibility than phenolic.

4) This enclosure or protection shall be such that any flame or molten material, which can be caused by an electrical disturbance in the wiring, cannot reach surrounding combustible material.

   This requirement does not apply to flexible external leads that require flexibility for disconnection, output leads of the fuel cell power system for example, that comply with 1).

   This requirement does not apply to leads that, if damaged, do not result in a hazard.

4.14.4 Emergency switching off requirements (disconnection) for connections for fuel cell power system

1) An emergency switching off control or battery connector when used as an emergency switching off device shall be accessible to the operator in the normal operating position at all times.

2) The emergency switching off device shall be capable of interrupting without danger the power supplies to all moving elements where an interruption does not increase the potential risk. It shall be capable of interrupting the normal maximum current (including motor starting current) by one of the following methods:

a) fuel cell connector for voltage up to and including DC 120 V DC. Above 120 V DC, provision shall be made to prevent the use of the battery connector for emergency switching off purposes;

b) manually actuated power switch directly disconnecting one line of power supply;

c) manually actuated control switch disconnecting the power supply to the coil of one contactor in one line of the power supply. Simultaneously the power controller (e.g. inverter or controller for separate excited motors) shall be deactivated. In trucks driven by series-wound DC motor(s) with mechanical commutator without power controller, two independent contactors are necessary to switch off battery supply.

In the case of b) or c), they shall be a positive action type in accordance with IEC 60947-5-1 and the actuator coloured red. See also IEC 60947-3.

A contrasting colour shall be used if the background is red.

It shall be possible to re-establish the power supply to the moving elements only by manual resetting of the switching off device followed by the normal operation of the controls.

3) If the fuel cell connector is used as an emergency switching off system, the removable part of the connector shall have a means for disconnecting without damage to the fuel cell connectors or cables.

4) When the connector is used for emergency switching off, the device shall be capable of being disconnected quickly in case of emergency and the two half-connectors shall be able to be separated easily. The maximum force to separate the two half connectors shall not exceed 150 N.

4.14.5 Motors

Motors shall comply with IEC 60034, unless they are located in limited power circuits.

A motor cannot comply with this requirement if located in a low voltage circuit.

4.14.6 Switches and motor controllers

1) A motor controller or switch shall be rated for the load that it controls. A motor controller shall have the current interrupting capacity not less than the locked rotor load of the motor controlled in accordance with IEC 60204-1 and shall comply with the additional requirements for motor controls as specified in ISO 20898.

2) A switch that controls an inductive load other than a motor, such as transformer, shall not be less than twice the rated full-load current of the transformer, or similar device, unless the switch has been investigated and found acceptable for the application.

4.14.7 Transformers and power supplies

1) Transformers located in hazardous voltage circuits shall be provided with overcurrent protection.

2) Class 2 and Class 3 transformers shall comply with IEC 60950-1 or IEC 61204-7.

3) Power supplies other than Class 2 shall comply with IEC 60950-1 or IEC 61204-7, as applicable.

4.14.8 Inverters, converters and controllers

Inverters, converters and controllers shall be subjected to the abnormal condition tests (faulted components) of IEC 62477-1.

4.14.9 Lamps and lampholders

1) Lamps and lampholders shall be totally enclosed. A lamp lens shall be protected against mechanical damage by bars, grids, recessing or equivalent means.

2) A light emitting diode (LED), vacuum fluorescent display (VFD), backlit liquid crystal display (LCD), and any other display that can be a source of ignition when mechanically damaged shall be protected against mechanical damage.

4.14.10 Energy storage components

4.14.10.1 Batteries

1) Secondary lithium batteries shall comply with IEC 62619 and shall be protected from reverse polarity charging.
2) Lead acid type batteries shall comply with IEC TS 61430.
3) Other chemistries, such as nickel-cadmium or nickel-metal-hydride cells, shall comply with IEC 62133-1.
4) For batteries employed as a fuel cell power system/power battery combination:
   a) Cells employing metal containers, such as alkaline batteries, shall be insulated from one another and from a metal tray or metal battery compartment. Insulation of wood or other material shall be:
      i) treated or painted to reduce deterioration by the battery electrolyte, and
      ii) constructed to reduce the risk of damage to the insulation during the normal operation and maintenance of the truck.
   b) Battery terminals shall be connected in a safe way avoiding any possibility that a conductive component could connect battery terminals generating an electric arc.
   c) Battery terminals shall be protected by insulating boots or covers, if applicable.
5) A terminal that is intended to be connected to ground on the truck frame can be provided with a boot or cover.

4.14.10.2 Double layer capacitors (ultracapacitors)

For ultracapacitors employed as a fuel cell power system/ultracapacitor combination:

1) Integral charging circuits for ultracapacitors which shall comply with IEC 62391-1 and IEC 62391-2 shall be provided with reliable means of protection from overvoltage charging conditions and if necessary, overcurrent charging and discharging conditions.
2) Ultracapacitors employing metal containers shall be insulated from one another and from a metal tray or metal capacitor compartment. Insulation shall be constructed to reduce the risk of damage to the insulation during the normal operation and maintenance of the truck.
3) The metal container of an ultracapacitor that is connected to the negative electrode of the capacitor (negative electrode and the metal container or not insulated internally from each other) shall be considered part of the negative electrode and shall be enclosed or provided with an insulating cover.
4) Ultracapacitor terminals shall be connected in a safe way avoiding any possibility that a conductive component could connect ultracapacitor terminals generating an electric arc.
5) Ultracapacitor terminals shall be protected by insulating boots or covers, if applicable.
6) A terminal that is intended to be intentionally connected to ground on the truck frame can be provided with a boot or cover.
7) Before maintenance or service of ultra-capacitors ensure they are fully discharged or the circuit shall be safely disconnected.

4.14.11 Electrical insulation

1) Materials employed as electrical insulation shall comply with ISO 1798, ISO 2440, ISO 179 (all parts), ISO 180 and ISO 877 (all parts).
2) The thickness of an insulating barrier employed as the sole insulation between uninsulated live parts and non-current carrying metal parts or between parts of opposite polarity shall be 0,71 mm thick minimum.
3) For a system with output rated 24 V DC or less, the thickness shall be 0,33 mm minimum.
4) For a system rated more than 24 V DC, where there is a minimum of half of the required acceptable spacing through air, a barrier or liner can be employed that has a minimum thickness of 0,33 mm.

5) For a system rated 24 V DC or less, the thickness shall be 0,15 mm minimum.

4.14.12 Limited power circuit

A limited power circuit shall comply with the test of 5.13.

4.14.13 Electrical spacings

The spacings in a fuel cell power system for industrial trucks shall not be less than as outlined in Table 2.

Minimum acceptable spacings are not specified in a limited power circuit as defined in 4.14.12.

Minimum acceptable spacings within a component shall be determined by the component document.

Minimum acceptable spacings can be reduced from that outlined in Table 2 if the circuits are evaluated in accordance with IEC 60664-1, and the following:

1) The reduced spacing requirements shall not be used at electrical connections to the truck or for spacings to a non-current carrying metal enclosure.
2) The fuel cell is to be rated for overvoltage category I and pollution degree 3 as defined in IEC 60664-1. Circuits provided with protective enclosures without ventilation openings to allow for the entrance of dust, humidity and other conductive debris can be considered pollution degree 2 and circuits that are in hermetically sealed or encapsulated enclosures can be considered pollution degree 1.
3) In order to apply clearance B (controlled overvoltage) clearances, control of overvoltage shall be achieved by providing an overvoltage device or system as an integral part of the fuel cell.
4) All printed wiring boards are considered to have a minimum comparative tracking index (CTI) of 100 (material group IIIb).

Table 2 – Spacings

Location	Nominal voltage 24 V DC or less		Nominal voltage greater than 24 V DC [a]	
	Through air mm	Over surface mm	Through air mm	Over surface mm
In a power circuit – between a bare live part and (1) a bare live part of opposite polarity, or (2) a bare grounded part other than the enclosure	1,6 [b]	3,2 [b]	3,2 [c]	6,4 [c]
In a power circuit at a location where conductive dust cannot accumulate, such as a small totally enclosed cavity [d]	0,8	1,6	1,6	3,2
In other than a power circuit – between a bare live part and (1) a bare live part of opposite polarity, or (2) a bare grounded part other than the enclosure	1,6	1,6	1,6	1,6
In other than a power circuit at a location where conductive dust cannot accumulate, such as a small totally enclosed cavity [d]	0,8	0,8	0,8	0,8
Between any uninsulated live part and the ultimate enclosure [e]	12,7	12,7	12,7	12,7
Between any uninsulated live part and the ultimate enclosure where the enclosure is formed of 3,2 mm thick cast metal or 6,4 mm thick steel plate [e]	6,4	6,4	6,4	6,4

NOTE A circuit is considered a power circuit if it supplies a motor-control circuit that is not provided with overcurrent protection. A circuit is not considered a power circuit if it supplies a circuit with overcurrent protection.

[a] Maximum of 150 V.

[b] These spacings apply to a system not electrically connected to the frame.

[c] These spacings also apply to a nominal 24 V DC or lower-voltage system electrically connected to the frame.

[d] Such as a point where a motor terminal passes through the motor frame.

[e] If deformation of the enclosure at the point of measurement of spacings is likely, the spacings after deformation shall be as specified.

4.14.14 Separation of circuits

1) A limited power circuit shall be separated from all other circuits either by:
   a) locating the circuit in a separate enclosure,
   b) proving through-air and over-surface spacings as noted in Table 2, or
   c) the use of barriers.

2) An internal wiring insulated conductor of a limited power circuit shall be either separated by barriers or segregated from live parts connected to different circuits or provided with insulation acceptable for the highest voltage involved.

3) The barriers noted in 1)c) may be bonded metal of not less than 0,51 mm thickness or of insulating material of not less than 0,71 mm thickness.

4) Conductors of circuits operating at different potential shall be reliably separated from each other unless they are each provided with insulation acceptable for the highest potential involved.

5) Electrical separation of an individual circuit shall be applied according to the requirements of IEC 60364-4-41:2005, Clause 413.

4.15 Control circuits

4.15.1 Safety controls

1) Electronic circuits relied upon for safety (a safety critical component, for example) shall be evaluated in accordance with IEC 607030-1:2013, IEC 60730-1:2013/AMD1:2015 and IEC 60730-1:2013/AMD2:2020, Annex H.

2) Software relied upon for safety as a safety critical component shall be evaluated in accordance with level C given in ISO 13849-1. The electronic hardware of the software safety system shall be evaluated in accordance with IEC 60730-1:2013, IEC 60730-1:2013/AMD1:2015 and IEC 60730-1:2013/AMD2:2020, Annex H.

3) As an alternative, electronic circuits and programmable software controls relied upon for safety can be evaluated according to IEC 61508 (all parts) or ISO 13849-1 and ISO 13849-2.

4.15.2 Start

1) The start of an operation shall only be possible when all of the safeguards are in place and are functioning in accordance with 4.16. The fuel cell power system shall be started only by an intentional operation of the start sequence unless it is determined that there is minimal risk with automatic restarting as determined by 4.16.

2) Restart of the fuel cell power system from a stop shall not result in a hazardous condition as determined by 4.16.

4.15.3 Drive off

1) The fuel cell power system shall include means to minimize the likelihood of moving the industrial truck with the fueling hose attached.

NOTE The drive off protection means can include an interlock switch in the fueling receptacle, an interlock circuit connected to the dispenser, or other means.

2) Switches, circuits, and the like used for drive off protection shall be suitable for the local area classification in which they are used. See 4.10 4).

4.15.4 Emergency stop

Fuel cell power systems shall be provided with an emergency stop mechanism.

4.16 Risk assessment and risk reduction

The manufacturer of the fuel cell power system shall conduct a risk assessment and perform risk reduction using the principles and methodology in accordance with ISO 12100, IEC/ISO 31010, IEC 60812, and IEC 61025.

NOTE Hazards addressed in the risk assessment and risk reduction include but are not limited to:

a) mechanical hazards, such as sharp edges or corners, protruding parts, moving parts, rotating or sliding parts, mass, and center of gravity;

b) liquids;

c) flammable or pressurized gases;

d) risk of fire and electric shock;

e) temperature, such as hot surfaces;

f) loss of output (loss of power to the industrial truck) and loss of control.

5 Performance requirements for safety and type tests

5.1 General

1) For the tests in 5.2 to 5.22, the fuel cell power system shall operate at maximum power with controls set to maximum normal limits, unless otherwise noted in the test methods.

2) As a result of the tests in 5.2 to 5.22 there shall be no leakage from parts containing liquid or gas that would result in a hazardous condition, unless otherwise noted.

5.2 Vibration test

5.2.1 General

1) A fuel cell power system shall be subjected to a system vibration test in both the vertical and longitudinal/lateral axes in accordance with 5.2.2 and 5.2.3. The fuel cell power system shall not be operating for these tests. As a result of the tests, the fuel cell power system shall comply with 5.5 and 5.6.

2) If the fuel cell power system is intended for use in an industrial truck with a known vibration profile, that profile can be used instead of the profile outlined in 5.2.2 and 5.2.3.

3) A self-contained fuel cell power system is to be tested outside of the truck in accordance with 5.2.2 and 5.2.3. The fuel cell power system is to be mounted using its own securement means, or a representative of the securement means, and secured to the test fixture of the vibration test apparatus in the same position which it occupies when in use.

4) An integrated fuel cell power system is not required to be tested in accordance with 5.2.2 and 5.2.3.

5) With reference to 3), individual components or sub-systems can be tested by themselves so long as they are mounted and supported as they can be in the complete system. Components normally mounted near the test subject shall be included or simulated if there is any chance of interference or contact between the parts.

5.2.2 Vertical axis test

The acceleration data for the vertical axis test shall be defined in collaboration with the truck manufacturer.

5.2.3 Longitudinal and lateral axes tests

The acceleration data for the longitudinal and lateral axis test shall be defined in collaboration with the truck manufacturer.

5.3 Fuel container securement test

1) Means shall be provided to secure fuel containers from becoming dislodged while in use or stored on the fuel cell power system. Lateral movement shall not exceed an amount that results in a hazardous condition. Any integral compressed gas fuel container shall include a connection fixture that will not allow the flow of gas until a positive gas seal has been achieved. The fuel connection device connecting the fuel supply and the system shall be suitable for its application.

2) A lateral force equal to the full weight of the fuel container or cylinder shall be applied in any direction at the centre of the vertical height of the fuel container or cylinder. The fuel container (i.e. fuel cylinder) or any portion thereof, shall not become dislodged from its retention means.

5.4 Endurance test

1) A fuel cell power system employing nonmetallic flammable fuel handling parts and/or flammable fuel pumps with dynamic seals shall be subjected to appropriate endurance testing in accordance with 2). The fuel cell power system shall comply with 5.7, before and after the test. There shall be no damage to the fuel cell power system that would result in a hazard. The fuel cell power system shall be operational.
2) The fuel cell power system shall be connected to a source of fuel and operated at a minimum of 50 % of the rated power output. This shall be done continuously for 720 h under normal operating pressures and temperatures.

5.5 External leakage test

All piping shall be leak tested in accordance with ISO 15649.

5.6 Dilution test

5.6.1 Releases

The leak rate for each potential release point in the fuel cell power system including any purge outlets shall be determined. See 4.10 and IEC 60079-10-1.

5.6.2 Setup and operation

1) The testing shall be carried out in a draft free area, with the system located at least 3,05 m from room vents or forced ventilation.
2) If the fuel cell power system uses mechanical ventilation, it shall be operated at the minimum flow rate that satisfies all interlocks. See 4.10.

5.6.3 Exhaust dilution

1) Hydrogen or equivalent gas shall be released at the determined leak rate and at the location of the largest potential release point in the fuel cell power system.
2) The diluted concentrations of flammable vapours exiting the fuel cell power system shall not exceed the limits of 4.10 2).

5.6.4 Dilution boundaries

1) Hydrogen or equivalent gas shall be released at the determined leak rate at each potential release point in the fuel cell power system.
2) The size and shape of each dilution zone shall be measured using a calibrated hydrogen or equivalent gas detector.
3) The analysis of 4.10 3) shall be confirmed or updated with the measured sizes and shapes of the dilution zones.
4) The requirements of 4.10 4) and 6) shall be confirmed with the measured sizes and shapes of the dilution zones.

NOTE In some cases it can be sufficient to place the hydrogen or equivalent gas detector at the locations of the nearest ignition source or unclassified equipment above and in the ventilation flow path, i.e. "downwind", of the release.

5.7 Ultimate strength test

1) A fuel cell module shall comply with the allowable working pressure test requirements of IEC 62282-2-100.
2) The oxidant and fuel sides of the cell stack can be interconnected and tested simultaneously at the same pressure.

5.8 Potential failure modes test

1) A review of the manufacturer's hazard analysis in accordance with 4.16 is done to determine the scope of this test procedure, including whether or not the system is to be operating during the test. Compliance with 5.8 can also be determined through supporting evidence provided by the manufacturer.
2) Critical failure modes, as identified in 4.16, are to be simulated to determine if the safety system is functional.
3) Compliance with 5.8 shall be determined by performance of the correct actions by the safety system in accordance with the manufacturer's risk assessment and risk reduction of 4.16.

5.9 Temperature test

1) A fuel cell system shall not attain a temperature at any point so as to result in a risk of fire, to damage any material used or to exceed the maximum temperatures specified in Table 3 when the unit operates at maximum rated output power in an ambient temperature as specified in 3).
2) A thermal or overload protective device shall not operate during this test.
3) All temperature rise values in Table 3 are based on an assumed ambient temperature of 25 °C. Tests can be conducted at any ambient temperature within the range of 10 °C to 40 °C when measured values are corrected by addition (if the ambient temperature is lower than 25 °C) or subtraction (if the ambient temperature is higher than 25 °C) of the difference between 25 °C and the ambient temperature.
4) Testing shall be continued until steady state temperatures are attained. Steady state temperatures are achieved when three successive readings taken at intervals of not less than 5 min indicate an increase in temperature less than 0,5 °C.
5) Temperatures shall be measured by means of thermocouples. Temperatures on coil windings can be measured by either thermocouples or change of resistance method.
6) Thermocouples shall consist of wires not larger than 0,21 mm^2 and not smaller than 0,05 mm^2. The thermocouple wire shall conform to the requirements specified in the tolerances on initial values of EMF versus temperature tables in IEC 60584-1.
7) When using the resistance method, the windings shall be at room temperature at the start of the test, and the temperature rise of a winding is to be calculated using the following formula:

$$\Delta t = \frac{R}{r}(k + t_1) - (k + t_2)$$

where

Δt is the temperature rise, expressed in °C;

R is the resistance of the coil, expressed in Ω at the end of the test;

r is the resistance of the coil, expressed in Ω at the beginning of the test;

t_1 is the initial room temperature, expressed in °C at the time resistance;

"r" is being measured (which is also the initial coil temperature);

t_2 is the room temperature, expressed in °C at the end of the test; and

k is 234,5 for copper and 225,0 for electrical conductor grade (EC) aluminium; values of the constant for other conductors are to be determined.

Table 3 – Temperature rise limits

Material and components	Temperature rise limits °C
Motors:	
Class 105 (A) insulation systems	
Thermocouple method	65
Resistance method	75
Class 130 (B) insulation systems	
Thermocouple method	85
Resistance method	95
Class 155 (F) insulation systems	
Thermocouple method	110
Resistance method	120
Class 180 (H) insulation systems	
Thermocouple method	125
Resistance method	135
Coils other than motors:	
Class 105 (A) insulation systems	
Thermocouple method	65
Resistance method	75
Class 130 (B) insulation systems	
Thermocouple method	85
Resistance method	95
Class 155 (F) insulation systems	
Thermocouple method	110
Resistance method	120
Class 180 (H) insulation systems	
Thermocouple method	125
Resistance method	135
Conductors:	
Rubber or thermoplastic insulated wires and cords (unless rated for higher temperatures)	35
Surface temperatures of components (unless rated for higher temperatures):	
Electrolytic capacitors [a]	–
Other capacitors [a]	–
Fuses	65

Material and components	Temperature rise limits °C
Electrical insulation (where deterioration would result in a safety hazard):	
Fibre	65
Laminated phenolic	100
Moulded phenolic	125
Other insulation materials [a]	–
Non-metallic enclosure, structural and functional materials [a]	–
Safety critical gaskets and seals [a]	–
Supporting and adjacent surfaces	65
A surface subject to continuous contact while the fuel cell power system is in use such as a momentary contact switch, etc.:	
Metallic	50
Non-metallic	60
A surface subject to deliberate contact while the fuel cell power system is in use, but not subject to continuous contact such as a switch:	
Metallic	60
Non-metallic	85
A surface subject to casual contact:	
Metallic	65
Non-metallic	83
[a] Temperature limits are dependent on the temperature rating of the material.	

5.10 Continuity test

1) Portions of the fuel cell power system intended to be bonded to the truck for electrostatic discharge protection shall be subjected to a bonding test.
2) Conductive parts required to be bonded to avoid electrostatic discharge shall have the impedance measured with a suitable ohmmeter between all points of connection of the metallic parts to determine that the resistance does not exceed 1 Ω.
3) Nonmetallic fluid lines shall have a maximum resistivity of 1 MΩ when evaluated in accordance with the conductivity test in IEC 60079-0 (the test will identify the required protection level and has standard references for the protection level).

5.11 Non-metallic tubing test for accumulation of static electricity

5.11.1 Passing criteria

No sparks shall be observed when a grounded metal sphere is brought into gradual contact with the non-metallic tubing after it has been electrostatically charged.

5.11.2 Test method

Three samples of the tubing with ground point electrodes (i.e. metal fittings) shall be conditioned for at least 48 h at a relative humidity of (25 ± 10) %.

Immediately after removal from the low-humidity chamber, the samples are to be supported by means of insulators in a room having a relative humidity not more than 35 % and having all sources of light, other than electrical sparks, eliminated. The ground point electrodes are to be grounded. An electrostatic charge is to be sprayed on nonconductive parts of the product using an electrostatic generator limited to 5 000 V.

A 9,5 mm diameter grounded metal sphere is to be brought into gradual contact with the sample. If no sparks appear, the sample passes the test.

5.12 Dielectric voltage – Withstand test

1) Each circuit (greater than 30 V RSM or 42,4 V peak or 60 V DC) of the fuel cell power system shall withstand, without breakdown, the application of an essentially sinusoidal potential at 50 Hz or 60 Hz of 1 000 V plus twice the rated voltage of the circuit if it is rated more than 72 V, or 500 V otherwise. Semiconductors or similar electronic components liable to be damaged by application of the test voltage can be bypassed or disconnected.

   DC potential equal to 1,414 times the value for the AC potential can be applied instead.

2) The test voltages shall be applied for a minimum of 1 min.

5.13 Limited power circuit test

1) A limited power source shall comply with one of the following:

   a) the output is inherently limited in compliance with Table 4;

   b) an impedance limited output in compliance with Table 4. If a positive temperature coefficient device is used, it shall comply with IEC 60730-1:2013, IEC 60730-1:2013/AMD1:2015 and IEC 60730-1:2013/AMD2:2020, Clause 15, Clause 17 and Annex J;

   c) a non-arcing over-current protective device is used and the output is limited in compliance with Table 5;

   d) a regulating network limits the output in compliance with Table 4 both under normal operating conditions and after any single fault conditions in the regulating network (open circuit or short circuit); or

   e) a regulating network limits the output in compliance with Table 4 under normal operating conditions and a non-arcing over-current protective device limits the output in compliance with Table 5 after any single-fault condition in the regulating network (open circuit or short circuit). If the overcurrent protection means is a discreet arcing device, further evaluation with respect to its isolation from potentially flammable gas should be made.

NOTE The reason for making measurements with overcurrent protection means bypassed is to determine the amount of energy that is available to cause possible overheating during the operating time of the overcurrent protection means.

2) The load referenced in footnotes b) and c) of Table 4 and Table 5 shall be adjusted to develop maximum current and power transfer, respectively. Single faults in a regulating network are applied under these maximum current and power conditions.

Table 4 – Limits for inherently limited power sources

Output voltage direct current [a] V_{oc}	Output current [b] I_{sc}	Apparent power [c] S
V	A	VA
≤ 20	≤ 8,0	≤ 5 × V_{oc}
20 < V_{oc} ≤ 30	≤ 8,0	≤ 100
30 < V_{oc} ≤ 60	≤ 150 / V_{oc}	≤ 100

[a] V_{oc}: Output voltage measured with all load circuits disconnected. Voltages are for ripple-free, direct current.

[b] I_{sc}: Maximum output current with any non-capacitive load, including short circuit, measured 60 s after application of load.

[c] S (VA): Maximum output VA with any non-capacitive load measured 60 s after application of load.

Table 5 – Limits for power sources not inherently limited (overcurrent protection required)

Output voltage [a] V_{oc}	Output current [b] I_{sc}	Apparent power [c] S	Current rating of overcurrent protection [d]
V	A	VA	A
≤ 20			≤ 5,0
20 < V_{oc} ≤ 30	≤ 1 000/V_{oc}	≤ 250	≤ 100/V_{oc}
30 < V_{oc} ≤ 60			≤ 100/V_{oc}

[a] V_{oc}: Output voltage measured with all load circuits disconnected. Voltages are for ripple free, direct current.

[b] I_{sc}: Maximum output current with any non-capacitive load, including short circuit, measured 60 s after application of load. Current limiting impedances in the equipment remain in the circuit during measurement, but overcurrent protection means are bypassed.

[c] S (VA): Maximum output VA with any non-capacitive load measured 60 s after application of load. Current limiting impedances in the equipment remain in the circuit during measurement, but overcurrent protection means are bypassed.

[d] The current ratings of the overcurrent protection means are based on fuses and circuit-breakers that break the circuit within 120 s with a current equal to 210 % of the current rating specified in the table.

5.14 Rated power output test

1) One sample of the fuel cell power system shall be subjected to a rated power output check in accordance with 3) and 4).

2) The duration of the rated power output check shall be determined by the manufacturer.

NOTE The maximum current is expected to continue for 3 h (or more) to define continuous load.

3) With the output of the fuel cell power system connected to a variable load, the rated power output of the system is to be measured. The load shall be capable of being varied from zero to short circuit during the test.

4) The rated power output of the system shall not exceed the marked rated output value (see Clause 7 2)c)), by more than ±10 %.

5.15 Abnormal operation test – Electric equipment failures

1) The fuel cell power system shall be subjected to the electrical component faults noted in 2) to 4). The introduced faults of the electrical components shall not result in a shock or fire hazard from the fuel cell power system.

2) The fault conditions are to be maintained for 7 h or until ultimate results occur. Ultimate results include thermal stabilization of the system or the opening of a fuse or other protective device.

3) The following fault conditions, as applicable to the system, are to be conducted:

   a) the fuel cell power system output short-circuited;

   b) the rotor of each blower or fan motor locked, one at a time, if the system relies upon forced ventilation;

   c) the polarity of batteries reversed, if the batteries employed in the system are user replaceable or the battery connector is not polarized;

   d) the fuel cell power system operating at maximum available power as determined by rated power output in 5.14, unless a fuse opens;

   e) the system operating at 135 % of the ampere rating of the protective fuse, with the fuse bypassed, if a fuse operates during condition d); and

   f) the absence of liquid supplied for liquid pumps that require a liquid for cooling purposes.

4) If a protective device opens during conditions 3)a) to 3)d) and 3)f), the test shall be

   a) terminated, if a non-resettable, non-automatic protector functions;

   b) continued for 7 h if an automatic-reset protector functions, or

   c) continued for 10 cycles at a rate not faster than 10 operations/min if a manual reset device operates.

5.16 Emission of effluents test (only for methanol fuel cells)

1) A methanol fuel cell power system capable of producing emissions of any materials given in Table 6 shall not exceed the emission limit in Table 6.

2) The methanol fuel cell power system shall be operated at rated power in an open room or outdoors. During the operation, a sufficient effluent sample shall be secured to allow a determination of compliance with Table 6.

3) The effluent sample shall be secured at a point of exhaust discharge of the methanol fuel cell power system. The results of the analyses shall be compared to the limits in Table 6. If the measured rate is less than the limit, the direct methanol fuel cell power system passes the test.

Table 6 – Emission rate limits

	Emission rate limit
Methanol	1,8 g/h
CO	0,20 g/h
CO_2	No limit

5.17 Environmental test

5.17.1 Rain test

Enclosures shall be compliant with IPX4 in accordance with IEC 60529. Compliance with IPX4 is demonstrated by testing required by IEC 60529. The external enclosure of the fuel cell power system shall comply with the appropriate testing requirements in accordance with IEC 60529, based the requirements of 4.13 2) and the IP rating of the product marked on the nameplate. See Clause 7 2)j).

IPX2 is acceptable for units designed and labelled for indoor operation only.

5.17.2 Test of equipment – Exposure to wind

1) A fuel cell power system fueled by methanol shall not create a hazardous or unsafe condition when exposed to winds having nominal velocities up to and including 16 km/h. Compliance with harmful effect is demonstrated by testing according to 2) to 4).
2) The fuel cell power system shall not be adversely affected by wind.
3) The fuel cell power system shall operate without damage or malfunctioning of any part and without creating a hazardous condition when exposed to winds having nominal velocities of 50 km/h or the manufacturer's rated maximum wind speed marked on the product, whichever is higher.
4) A wind produced by a fan or blower having a velocity of 50 km/h or the manufacturer's rated maximum wind speed marked on the product, whichever is higher, is to be directed against an outer surface of the fuel cell power system at directions considered worse case. The fan or blower is to be located so that a uniform wind, covering the entire projected area of the outer surface of the system, is directed horizontally toward the fuel cell power system at the specified velocity measured in a vertical plane 457,2 mm from the windward surface of the fuel cell power system.

5.18 Enclosure tests

5.18.1 Enclosure loading test

The self-contained fuel cell power system's external enclosure housing shall be constructed so that a loading force of 1 110 N, applied for 1 min on the top of the external enclosure, does not cause damage to the fuel cell, shorting of electrical spacings within the fuel cell, or other hazards.

5.18.2 Test for thermoplastic enclosures

5.18.2.1 Impact test

A thermoplastic external enclosure shall comply with IEC 60695-10-2. The enclosure shall also be subjected to an impact of 136 J. The impact test is to be conducted by dropping a steel sphere, 101,6 mm in diameter and weighing 4,5 kg, from a height of 3,0 m.

5.18.2.2 Cold impact test

A fuel cell power system intended for cold temperature use marked for use at or below –20 °C in accordance with Clause 7 2)f) that utilizes a thermoplastic external enclosure shall comply with the cold impact test, minus 30 °C conditioning or 10 °C below the marked rated temperature, whichever is lower, in accordance with IEC 60695-1-30 and IEC 60695 (all parts), except that the enclosure shall be subjected to an impact of 136 J during the test. The test shall be conducted by dropping a steel sphere, 101,6 mm in diameter and weighing 4,5 kg, from a height of 3,0 m.

5.18.2.3 Mould stress test

1) A thermoplastic external enclosure of a fuel cell power system shall be suitable for the range of temperatures that it is subjected to during use.
2) A thermoplastic enclosure shall be subjected to the test in accordance with IEC 60695-10-2.
3) As a result of the mould stress test, there shall be no warping, melting or other deformation of the external enclosure that would expose hazardous parts, or affect ventilation or other systems that could affect safe operation of the fuel cell power system.

5.18.2.4 20 mm moulded part needle flame test for thermoplastic materials

1) As an alternative to classifying thermoplastic external enclosure materials as V-0 or V-1, a 20 mm flame test of the moulded part(s) as outlined in 5.19 2) to 4) can be conducted.
2) The test shall be conducted by employing the apparatus and test flame described in IEC 60695-11-4.

3) Two 30 s applications of the tip of the 20 mm flame shall be made to each section of the enclosure selected as indicated above, with 1 min intervals between applications. A supply of technical grade methane gas shall be used with a regulator and meter for uniform gas flow.

4) The enclosures shall not flame for more than 1 min after two 30 s applications of a test flame with an interval of 1 min between applications of the flame. The results are not acceptable if the sample is completely consumed.

5.19 Marking plate adhesion test

1) To determine if a marking plate secured by adhesion complies with Clause 7, representative samples shall be subject to 2) to 5). In each test, three samples of the marking plates shall be applied to the same test surfaces as employed in the intended application.

2) Immediately following each of the tests in 3) to 5) and after exposure to room temperature for 24 h, each sample shall

   a) demonstrate good adhesion and the edges shall not be curled,

   b) resist defacement or removal as demonstrated by scraping across the test panel with a flat metal blade 1,76 mm thick, held at a right angle to the test panel, and

   c) have legible printing that is not defected by rubbing with thumb or finger pressure. Printing should resist removal from general cleaning chemicals or by rubbing with thumb or finger pressure.

3) For air-oven ageing, three samples of the marking plates shall be placed in an air-circulating oven maintained at a temperature of 85 °C for 240 h.

4) For immersion testing, three samples of the marking plates shall be placed in a controlled atmosphere maintained at (23 ± 2) °C with a (50 ± 5) % relative humidity for 24 h. The samples shall then be immersed in water at a temperature of (23 ± 2) °C for 48 h.

5) For standard atmosphere testing, three samples of the marking plates shall be placed in a controlled atmosphere, maintained at (23 ± 2) °C with (50 ± 5) % relative humidity for 72 h.

5.20 Test for elastomeric seals, gaskets and tubing

5.20.1 General

Elastomeric seals, gaskets and tubing relied upon for safety shall be subjected to the test in 5.20.2 and in 5.20.3, as applicable.

5.20.2 Accelerated air-oven ageing test

Elastomeric seals, gaskets and tubing relied upon for safety shall be suitable for temperatures encountered and shall comply with the test in accordance with ISO 16010.

5.20.3 Cold temperature exposure test

1) Elastomeric seals, gaskets and tubing relied upon for safety and intended for extreme cold temperature use systems rated at or below –20 °C shall not become brittle to the extent that they will not function as intended as a result of 2).

2) Parts described in 5.20.1 shall be subjected to the test in accordance with ISO 16010.

5.20.4 Immersion test

Elastomeric seals, gaskets and tubing relied upon for safety shall be suitable for exposure to fluids such as methanol encountered in use and shall comply with the volume change test in Liquid B in accordance with ISO 16010 except that the test liquid shall be representative of the liquid the material will be exposed to (i.e. 100 % methanol or a methanol blend) and the volume change allowed shall be (25 ±1) % of the as-received value.

5.21 Test for permeation of non-metallic tubing and piping

1) Non-metallic tubing and piping containing flammable gas shall be sufficiently nonpermeable to those gases.
2) Non-metallic tubing and piping shall be subjected for permeability to hydrogen in accordance with ISO 4080.

5.22 Test for electrical output leads

1) The electrical output power leads of a fuel cell power system intended for exposure to extreme temperatures above 50 °C and at or below –20 °C shall be constructed so that they can withstand the test in 2) based upon the extreme temperatures as marked in accordance with Clause 7 2)f). These tests do not apply to low-voltage circuits.
2) Parts described in 1) shall be subjected to the test in accordance with ISO 16010, at 10 K higher than the marked temperature rating, but no less than 70 °C for 168 h. After conditioning, the leads shall be examined for signs of deterioration such as cracking and melting.

Leads with insulation marked with a temperature rating meeting the high temperature marked on the system in accordance with Clause 7 2)f) are not required to be subjected to this test.

5.23 Emergency stop

1) The effectiveness of each emergency stop actuator and device shall be confirmed by test.
2) The fuel cell power system shall be energized sufficiently to perform the test. Circuits and components can be energized using batteries or external sources rather than operating the fuel cell using a flammable gas as long as all emergency stop functions can be confirmed.
3) Each emergency stop actuator and device is to be activated individually.
4) The stopping and removal of power to each individual fuel cell power system actuator controlled by the emergency stop is to be confirmed for each emergency stop actuator and device. Fuel cell power system actuators can include motors, valves, pumps, blowers, fans, and the like.

6 Routine tests

6.1 External leakage

1) An external leakage on the flammable fluid containing portions of the system shall be subjected to an external leak test on 100 % of the production.
2) While under normal operating pressures, the gas containing portions of the system shall not leak after operation for 1 min. Visible signs of soap bubbles, pressure decay or similar occurrences, as applicable to the method of test, shall indicate leaks in the system.
3) The fuel cell power system shall be operated, or the parts under test pressurized at normal operating pressure. Areas for potential leaks such as at fittings are to be tested for leaks using a soap and water leak detection solution or equivalent means.

6.2 Dielectric voltage-withstand test

The test in 5.12 shall be conducted on 100 % of the production except that the time can be lowered to 1 s if the test potential is increased by 120 % of the rated voltage (1 000 + 2,4 × V_{rated}).

This production line test is not required to be conducted on low-voltage circuits.

7 Markings

1) The nameplate markings specified in 2) shall be permanently secured to the fuel cell power system. If an adhesive is used to secure the marking plate on the fuel cell, then the adhesive shall comply with the test of 5.19.

2) The fuel cell power system marking plate shall include the following:
   a) the manufacturer's name, trademark or other descriptive marking by which the organization responsible for the product can be identified;
   b) a catalogue number or the equivalent;
   c) output electrical rating in nominal system volts, maximum continuous amperes and the rated power output;
   d) type of fuel utilized, including service pressure and maximum operating pressure;
   e) where the fuel tank is fixed and not easily viewed, the label shall include the total fuel container water volume, in litres, along with the re-test date(s) or expiration date;
   f) minimum and maximum ambient operating temperatures;
   g) minimum and maximum storage temperatures, if different from f);
   h) weight of the fuel cell power system, for self-contained systems only;
   i) centre of gravity of the fuel cell power system, for self-contained systems only; and
   j) an IP rating shall be provided on a fuel cell power system that complies with 4.13 1), 2), and 3), and 5.18.1;
3) All other required markings in a) to h) shall be permanent in accordance with IEC 60950-1:2005, 1.7.11:
   a) a fuel cell power system intended for field installation shall also include a marking indicating that the system is intended for field installation by qualified personnel only;
   b) systems provided with replaceable fuses shall be marked with the current and voltage rating of the fuse near the fuse holder;
   c) the polarity of the output leads shall be marked on the leads unless they are terminated in a polarized connector;
   d) the fuel cell power system shall be marked to indicate that it has to be properly connected to the truck equipotential bonding system;
   e) with reference to 4.6 4), where a manual valve is used for flammable gas supplied to the fuel cell power system, the valve shall be indicated with a marking of the words "MANUAL SHUTOFF";
   f) nameplate and documentation of tanks shall include the effective end of service date of the pressure vessels based upon the worse case analysis;
   g) markings shall be in the language(s) of the country in which the truck is to be used, in accordance with national law (ISO 3691-1). A pictogram is also sufficient; and
   h) the use of symbols should also be in accordance with ISO 7010 and/or ISO 3864-1.

8 Instructions

8.1 General

1) The fuel cell power system shall be provided with an instruction manual in the national language of the operation country.
2) The instruction manual shall include maintenance, operating and installation instructions in accordance with 8.2 to 8.4.
3) The instruction manual shall include a sufficient electrical and fuel line documentation to install, operate, and maintain the fuel cell power system. This documentation shall include all information necessary to connect the fuel cell power system to the truck, refuel the fuel cell power system, and replace any regular maintenance items.
4) The operating and storage instructions shall describe the possible hazards resulting from the use of fuels and any precautions to be taken when handling the materials.
5) Information giving requirements for installation, maintenance, charging and handling shall be included in the fuel cell and/or truck installation manual.
6) The manual shall include information about recycling and handling of a damaged fuel cell.

8.2 Maintenance instructions

The maintenance instructions shall include the following, as applicable:

1) For a fuel cell power system provided with replaceable batteries, instructions for battery replacement including the type and rating of the batteries.
2) For a fuel cell power system with replaceable fuses, instructions for replacement of fuses including the type, voltage and current rating of the fuses.
3) Instructions regarding the need to keep all ventilation and exhaust openings from becoming blocked so that air is not obstructed and that any required clearances to maintain suitable ventilation and exhaust shall be maintained when installed in the truck.
4) Instructions for basic inspection and maintenance such as filter cleaning, replacement of parts, and lubrication of parts. See also 4.14.2 6).
5) The source for replacement parts.
6) An explanation of the necessity for, and the minimum frequency of, periodic examinations and inspections by qualified personnel. For example, the checking of any safety critical components requiring calibration such as gas detectors and pressure switches.
7) The fuel cell display shall show if maintenance is necessary or the fuel cell manufacturer shall specify when maintenance is necessary and indicate it.

8.3 Operating instructions

The operating instructions shall include the following, as applicable:

1) Instructions for starting up and shutting down the fuel cell power system.
2) Complete instructions for the proper refuelling of the fuel cell power system including a warning not to drive or move the truck with the refueling hose or interface cable connected.
3) For a fuel cell power system with no IP rating for ingress of water, the statement

"WARNING: not rated for use in high humidity up to 95 %, wet, or rainy conditions."

4) For a fuel cell power system not designed for temperature extremes, the statement,

"WARNING: not rated for use below ___ degrees. Not rated for use above ___ degrees."

5) Information regarding provisions for adequate process and ventilation air. This shall include the following statement "This fuel cell power system uses oxygen from the area in which it is being used. It should not be used in a confined space or unusually tight construction, unless provisions are provided for adequate process and ventilation air." An example for determining the volume of a typical area should also be included.

NOTE Unusually tight construction is considered as construction where

1) walls and ceiling exposed to the outside atmosphere have a continuous water vapour retarder with a rating of 6×10^{-11} kg/(m^2 × Pa × s) (1 perm) or less with openings gasketed or sealed;
2) weather stripping has been added on windows and doors that are able to be opened; and
3) caulking or sealants are applied to areas such as joints around window and door frames, between sole plates and floors, between wall-ceiling joints, between wall panels, at penetrations for plumbing, electrical and gas lines, and at other openings.

8.4 Installation instructions

1) Instructions shall be provided for the proper installation of the fuel cell power system including, but not limited to, spacings requirements, location of ventilation and exhaust openings, securement, electrical connections and fuel connections. Where a hazard can be present through system orientation or positioning, instructions shall be provided and the system so labelled.
2) The installation instructions shall have instructions regarding the proper equipotential bonding of the fuel cell power system to the truck chassis, see 4.11 5).
3) If storage tanks are provided, instructions for the proper installation of the storage system including instructions for the connections of the fuel lines to the fuel cell power system shall be included.
4) The installation instructions for a field installed fuel cell power system shall include a statement indicating that the system is intended for field installation by qualified personnel only.

Annex A
(informative)

Comparison of pressure terms

Comparison of pressure terms is given in Table A.1 as information.

Table A.1 – Comparison table of pressure terms

Pressure terminology	Standards/codes				
	ISO 19881 (2018)	NFPA 52 (2019)	ASME B & PV Code Sec. VIII	SAE J2600 (2015)	UL 2267 (2020)
Service pressure (SP)	–	Same as NWP	–	–	25 Mpa or 35 MPa
Nominal working pressure (NWP) or just working pressure (WP)	WP same as NWP or SP	–	–	Same as SP	–
Maximum operating pressure (MOP)	–	1,25 × SP, same as MFP	–	1,25 × NWP, same as MFP	1,25 × SP, 31,25 MPa or 43,75 MPa
Maximum fill pressure (MFP)	1,25 × WP, same as MOP	–	–	1,25 × NWP, same as MOP	–
Design pressure	–	–	DP	–	–
Maximum allowable working pressure (MAWP)	–	1,38 × SP	MAWP	1,38 × NWP	1,38 × SP, 34,5 MPa or 48,3 MPa

Annex B
(informative)

Significant hazards, hazardous situations and events dealt with in this document

Requirement	Relevant yes / no?	Fulfilled by
1. Principles of safety integration	Yes	Application IEC Guide 116
2. Requirements regarding design and construction		
2.1 Protection against electric shock and other electrical hazards		
• leakage current (e.g. due to insulation fault)	Yes	4.14.13
• energy supply	Yes	4.14.7
• stored charges	Yes	4.14.10
• switching arc and arc fault	Yes	4.11, 4.14.2, 4.14.3
• electric shock	Yes	5.10, 5.12, 6.2
• burns	Yes	4.4
2.2 Protection against fire hazards		
• external ignition	Yes	5.15
• internal ignition	Yes	5.15
2.3 Protection against mechanical hazards		
• instability	Yes	5.4
• break-down during operation	Yes	5.4
• falling or ejected objects	Yes	4.16
• rough surfaces, sharp edges or corners	Yes	4.13, 4.16
• moving parts, especially where there may be variations in the rotational speed of parts	Yes	4.14.5, 4.16
• vibration	Yes	5.2
• improper fitting of parts	Yes	4
2.4 Protection against other hazards		
• explosion caused by the equipment itself or by substances which may be produced, emitted or used by the equipment	Yes	5.8
• implosion	Yes	5.7
• acoustic noise	No	
• excessive temperature of materials ejected or accessible non-working surfaces likely to be touched	Yes	5.9
• adverse biological and/or chemical phenomena	Yes	4.12
• hygiene conditions	Yes	4.12

Requirement	Relevant yes / no?	Fulfilled by
• emissions, production and/or use of hazardous substances (e.g. gases, liquids, dusts, mists, vapour)	Yes	4.12, 5.16
• ageing of materials	Yes	5.4
• unattended operation	No	
• connection to and interruption from power supply	Yes	4.14.12
• combination of equipment	Yes	4.14.14
2.5 Protection against hazards arising from incorrect functioning		
• expected environmental conditions, including electric, magnetic and electromagnetic disturbances considered as relevant in the product or generic EMC standard	Yes	5.8
• logic errors in hardware or software	Yes	4.16
• interruptions or normally expected fluctuations in the power supply	Yes	4.14.12
• unexpected starting or stopping operation	Yes	4.15
• failure to stop or to start	Yes	4.15
2.6 Protection against hazards arising from electric, magnetic, and electromagnetic fields, other ionizing and non-ionizing radiation	Yes	4.11, 4.14.1
2.7 Ergonomics	No	
3. Information requirements		
• Information provided with the equipment shall include instructions for safe installation, maintenance, cleaning, operation and storage.	Yes	8.2, 8.3
• Where risks remain despite all the measures adopted or in the case of potential risks, which are not evident, appropriate warnings shall be provided.	Yes	8.3
• The essential characteristics, the recognition and observance of which will ensure that equipment will be used safely and in applications for which it was intended and for which it can reasonably be foreseen, shall be marked legibly and indelibly on the equipment or, if this is not possible, in the accompanying instruction for use.	Yes	7
• Information provided either by marking or in the instructions for use, which is essential for the safe use of the equipment, shall be easily understandable by the intended user.	Yes	7, 8

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

_____

TECHNOLOGIES DES PILES À COMBUSTIBLE –

Partie 4-101: Systèmes à pile à combustible pour chariots de manutention électriques – Sécurité

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La Norme internationale IEC 62282-4-101 a été établie par le comité d'études 105 de l'IEC: Technologies des piles à combustible.

Cette deuxième édition annule et remplace la première édition parue en 2014. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) révision du titre du présent document;
b) révision des normes de référence;
c) ajout de nouveaux paragraphes (4.3, 4.14.5, 4.15.3, 4.15.4, 4.16, 5.6 et 5.23);

d) renumérotation du paragraphe 4.15 de la version précédente en "4.16 Appréciation du risque et réduction du risque";

e) révision de 4.6 3) concernant l'accès au robinet d'arrêt manuel;

f) révision des exigences relatives aux bornes filetées de la batterie (4.14.10.1);

g) révision des exigences relatives aux condensateurs à double couche (4.14.10.2);

h) révision de l'essai de fuites externes (5.5) et de l'essai de résistance à la rupture (5.7);

i) révision des limites de température des condensateurs dépendant des caractéristiques assignées de tenue en température du matériau (Tableau 3);

j) révision des marquages non pertinents (Article 7);

k) ajout d'une nouvelle annexe informative (Annexe B) "Phénomènes dangereux significatifs, situations et événements dangereux traités dans le présent document".

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
105/912/FDIS	105/922/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

Une liste de toutes les parties de la série IEC 62282, publiées sous le titre général *Technologies des piles à combustible*, se trouve sur le site web de l'IEC.

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INTRODUCTION

La série IEC 62282-4 traite d'aspects tels que la sécurité, les performances et l'interchangeabilité des systèmes à pile à combustible utilisés pour la propulsion, autres que les véhicules routiers et groupes auxiliaires de puissance (GAP). Parmi les catégories mentionnées ci-dessus, le présent document, l'IEC 62282-4-101, porte sur la sécurité des chariots de manutention électriques comportant des systèmes à pile à combustible, car de telles applications sont instamment demandées dans le monde. Les futurs documents de la présente partie de l'IEC 62282-4 traiteront d'autres applications relatives aux véhicules embarqués autres que les véhicules routiers et les groupes auxiliaires de puissance (GAP).

TECHNOLOGIES DES PILES À COMBUSTIBLE –

Partie 4-101: Systèmes à pile à combustible pour chariots de manutention électriques – Sécurité

1 Domaine d'application

Le présent document traite des systèmes à piles à combustible pour la propulsion, autres que les véhicules routiers et groupes auxiliaires de puissance (GAP).

La présente partie de l'IEC 62282 couvre les exigences de sécurité relatives aux systèmes à pile à combustible destinés à être utilisés sur des chariots de manutention électriques, définies dans l'ISO 5053-1, à l'exception des chariots suivants:

– chariots tout-terrain;
– chariots cavaliers élévateurs non gerbeurs;
– chariots cavaliers élévateurs gerbeurs;
– chariots tout-terrain à portée variable;
– chariots tout-terrain rotatifs à portée variable;
– chariots porte-conteneur à portée variable;
– chariots à propulsion manuelle.

Le présent document s'applique aux systèmes à pile à combustible utilisant de l'hydrogène gazeux et à ceux utilisant du méthanol direct pour les chariots de manutention électriques.

Les combustibles suivants relèvent du domaine d'application du présent document:

– hydrogène gazeux ;
– méthanol.

Le présent document couvre le système à pile à combustible défini en 3.8 et à la Figure 1.

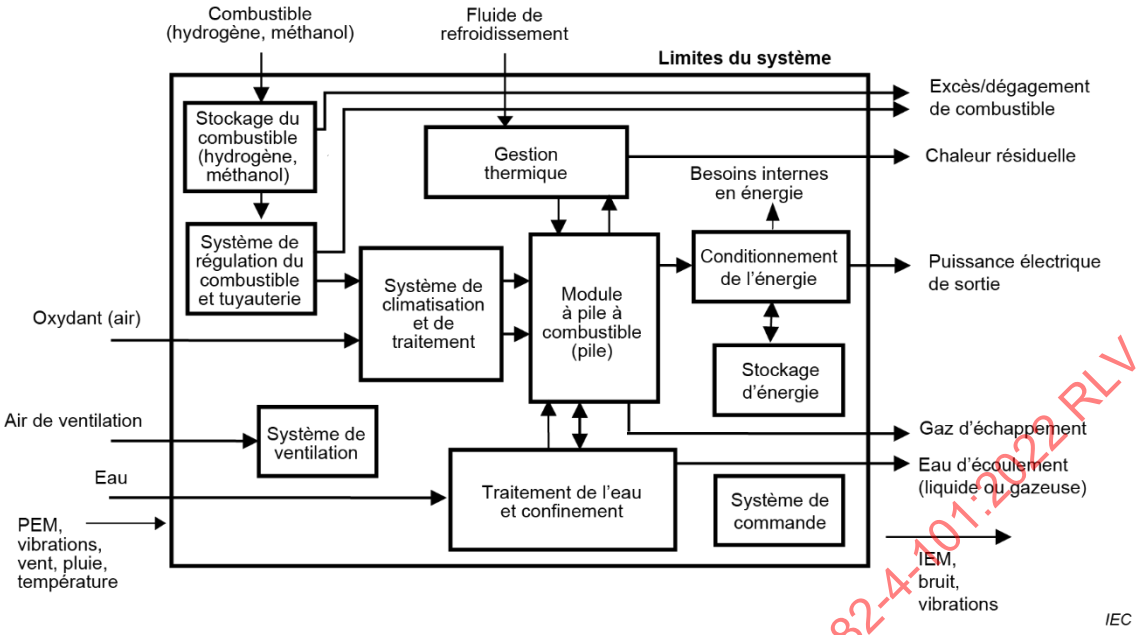
Le présent document s'applique aux systèmes à pile à combustible de type à courant continu, d'une tension de sortie assignée d'au maximum 150 V en courant continu pour utilisation à l'intérieur et à l'extérieur.

Il couvre également les systèmes à pile à combustible dont le conteneur de source de combustible est fixé à demeure, soit au chariot de manutention, soit au système à pile à combustible.

Conformément à l'IEC Guide 116, les phénomènes dangereux significatifs, les situations et événements dangereux traités dans le présent document sont représentés à l'Annexe B.

Les éléments suivants ne sont pas inclus dans le domaine d'application du présent document:

– les conteneurs de source de combustible de type amovible;
– les chariots hybrides qui comprennent un moteur à combustion interne;
– les systèmes à pile à combustible équipés de reformeurs;
– les systèmes à pile à combustible prévus pour être utilisés dans des atmosphères explosibles;
– les systèmes de stockage de combustible utilisant de l'hydrogène liquide.



Légende

EMD perturbation électromagnétique

EMI brouillage électromagnétique

NOTE Un système à pile à combustible peut comporter l'ensemble ou certains des éléments ci-dessus.

Figure 1 – Systèmes à pile à combustible pour chariots de manutention

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60050-485, *Vocabulaire électrotechnique international (IEV) – Partie 485: Technologies des piles à combustible*

IEC 60079-0, *Atmosphères explosives – Partie 0: Matériel – Exigences générales*

IEC 60079-10-1, *Atmosphères explosives – Partie 10-1: Classification des emplacements – Atmosphères explosives gazeuses*

IEC 60079-29-1, *Atmosphères explosives – Partie 29-1: Détecteurs de gaz – Exigences d'aptitude à la fonction des détecteurs de gaz inflammables*

IEC 60079-29-4, *Atmosphères explosives – Partie 29-4: Détecteurs de gaz – Exigences d'aptitude à la fonction des détecteurs de gaz inflammables à chemin ouvert*

IEC 60204-1, *Sécurité des machines – Equipement électrique des machines – Partie 1: Exigences générales*

IEC 60227-3, *Conducteurs et câbles isolés au polychlorure de vinyle, de tension nominale au plus égale à 450/750 V – Partie 3: Conducteurs pour installations fixes*

IEC 60227-5, *Conducteurs et câbles isolés au polychlorure de vinyle, de tension nominale au plus égale à 450/750 V – Partie 5: Câbles souples*

IEC 60335-2-41, *Appareils électrodomestiques et analogues – Sécurité – Partie 2-41: Exigences particulières pour les pompes*

IEC 60335-2-80, *Appareils électrodomestiques et analogues – Sécurité – Partie 2-80: Exigences particulières pour les ventilateurs*

IEC 60364-4-41:2005, *Installations électriques à basse tension – Partie 4-41: Protection pour assurer la sécurité – Protection contre les chocs électriques*
IEC 60364-4-41:2005/AMD1:2017

IEC 60529, *Degrés de protection procurés par les enveloppes (Code IP)*

IEC 60584-1, *Couples thermoélectriques – Partie 1: Spécifications et tolérances en matière de FEM*

IEC 60664-1, *Coordination de l'isolement des matériels dans les réseaux d'énergie électrique à basse tension – Partie 1: Principes, exigences et essais*

IEC 60695 (toutes les parties), *Essais relatifs aux risques du feu*

IEC 60695-1-30, *Essais relatifs aux risques du feu – Partie 1-30: Lignes directrices pour l'évaluation des risques du feu des produits électrotechniques – Processus d'essai de présélection – Lignes directrices générales*

IEC 60695-10-2, *Essais relatifs aux risques du feu – Partie 10-2: Chaleurs anormales – Essai à la bille*

IEC 60695-11-4, *Essais relatifs aux risques du feu – Partie 11-4: Flammes d'essai – Flamme de 50 W – Appareillage et méthodes d'essai de vérification*

IEC 60695-11-10, *Essais relatifs aux risques du feu – Partie 11-10: Flammes d'essai – Méthodes d'essai horizontal et vertical à la flamme de 50 W*

IEC 60730-1:2013, *Dispositifs de commande électrique automatiques – Partie 1: Exigences générales*
IEC 60730-1:2013/AMD1:2015
IEC 60730-1:2013/AMD2:2020

IEC 60812, *Analyse des modes de défaillance et de leurs effets (AMDE et AMDEC)*

IEC 60947-3, *Appareillage à basse tension – Partie 3: Interrupteurs, sectionneurs, interrupteurs-sectionneurs et combinés-fusibles*

IEC 60947-5-1, *Appareillage à basse tension – Partie 5-1: Appareils et éléments de commutation pour circuits de commande – Appareils électromécaniques pour circuits de commande*

IEC 60950-1:2005, *Matériels de traitement de l'information – Sécurité – Partie 1: Exigences générales*
IEC 60950-1:2005/AMD1:2009
IEC 60950-1:2005/AMD2:2013

IEC 61025, *Analyse par arbre de panne (AAP)*

IEC 61204-7, *Alimentations à découpage basse tension – Partie 7: Exigences de sécurité*

IEC TS 61430, *Accumulateurs – Méthodes d'essai pour la vérification de la performance des dispositifs conçus pour réduire les risques d'explosion – Batteries de démarrage au plomb*

IEC 61508 (toutes les parties), *Sécurité fonctionnelle des systèmes électriques/électroniques/électroniques programmables relatifs à la sécurité*

IEC 61558-1, *Sécurité des transformateurs, bobines d'inductance, blocs d'alimentation et des combinaisons de ces éléments – Partie 1: Exigences générales et essais*

IEC 62477-1, *Exigences de sécurité applicables aux systèmes et matériels électroniques de conversion de puissance – Partie 1: Généralités*

IEC 62133-1, *Accumulateurs alcalins et autres accumulateurs à électrolyte non acide – Exigences de sécurité pour les accumulateurs portables étanches, et pour les batteries qui en sont constituées, destinés à l'utilisation dans des applications portables – Partie 1: Systèmes au nickel*

IEC 62282-2-100, *Technologies des piles à combustible – Partie 2-100: Modules à piles à combustible – Sécurité*

IEC 62391-1, *Condensateurs électriques fixes à double couche utilisés dans les équipements électriques et électroniques – Partie 1: Spécification générique*

IEC 62391-2, *Condensateurs électriques fixes à double couche utilisés dans les équipements électroniques – Partie 2: Spécification intermédiaire – Condensateurs électriques à double couche pour application de puissance*

IEC 62619, *Accumulateurs alcalins et autres accumulateurs à électrolyte non acide – Exigences de sécurité pour les accumulateurs au lithium pour utilisation dans des applications industrielles*

IEC/ISO 31010, *Management du risque – Techniques d'appréciation du risque*

ISO 179 (toutes les parties), *Plastiques — Détermination des caractéristiques au choc Charpy*

ISO 180, *Plastiques – Détermination de la résistance au choc Izod*

ISO 877 (toutes les parties), *Plastiques – Méthodes d'exposition au rayonnement solaire*

ISO 1419, *Supports textiles revêtus de caoutchouc ou de plastique – Essais de vieillissement accéléré*

ISO 1421, *Supports textiles revêtus de caoutchouc ou de plastique – Détermination de la force de rupture et de l'allongement à la rupture*

ISO 1798, *Matériaux polymères alvéolaires souples – Détermination de la résistance à la traction et de l'allongement à la rupture*

ISO 2440, *Matériaux polymères alvéolaires souples et rigides – Essais de vieillissement accéléré*

ISO 2626, *Cuivre – Essai de fragilisation par chauffage dans l'hydrogène*

ISO 3691-1, *Chariots de manutention – Exigences de sécurité et vérification – Partie 1: Chariots de manutention automoteurs, autres que les chariots sans conducteur, les chariots à portée variable et les chariots transporteurs de charges*

ISO/TS 3691-7, *Chariots de manutention – Exigences de sécurité et vérification – Partie 7: Exigences régionales pour les pays de la Communauté européenne*

ISO/TS 3691-8, *Chariots de manutention – Exigences de sécurité et vérification – Partie 8: Exigences régionales pour les pays en dehors de la Communauté européenne*

ISO 3864-1, *Symboles graphiques – Couleurs de sécurité et signaux de sécurité – Partie 1: Principes de conception pour les signaux de sécurité et les marquages de sécurité*

ISO 4038, *Véhicules routiers – Dispositifs de freinage hydraulique – Tuyauteries à simple renflement, logements, raccords mâles et embouts de flexibles*

ISO 4080, *Tuyaux et flexibles en caoutchouc et en plastique – Détermination de la perméabilité au gaz*

ISO 4675, *Supports textiles revêtus de caoutchouc ou de plastique – Essai de flexion à basse température*

ISO 5053-1, *Chariots de manutention – Vocabulaire – Partie 1: Types de chariots de manutention*

ISO 7010, *Symboles graphiques – Couleurs de sécurité et signaux de sécurité – Signaux de sécurité enregistrés*

ISO 10380, *Tuyauteries – Tuyaux et tuyauteries métalliques flexibles onduleux*

ISO 10442, *Industries du pétrole, de la chimie et du gaz naturel – Compresseurs d'air centrifuges assemblés à multiplicateur intégré*

ISO 10806, *Tuyauteries – Raccords pour tuyaux métalliques flexibles onduleux*

ISO 11114-4, *Bouteilles à gaz transportables – Compatibilité des matériaux des bouteilles et des robinets avec les contenus gazeux – Partie 4: Méthodes d'essai pour le choix des aciers résistants à la fragilisation par l'hydrogène*

ISO 12100, *Sécurité des machines – Principes généraux de conception – Appréciation du risque et réduction du risque*

ISO 13226, *Caoutchouc – Elastomères de référence normalisés (SRE) pour la caractérisation de l'effet des liquides sur les caoutchoucs vulcanisés*

ISO 13849-1, *Sécurité des machines – Parties des systèmes de commande relatives à la sécurité – Partie 1: Principes généraux de conception*

ISO 13849-2, *Sécurité des machines – Parties des systèmes de commande relatives à la sécurité – Partie 2: Validation*

ISO 14113, *Matériel de soudage aux gaz – Tuyaux souples et flexibles en caoutchouc et en plastique pour des gaz industriels jusqu'à 450 bar (45 MPa)*

ISO 15649, *Industries du pétrole et du gaz naturel – Tuyauteries*

ISO/TR 15916, *Considérations fondamentales pour la sécurité des systèmes à l'hydrogène*

ISO 16010, *Garnitures d'étanchéité en élastomères – Exigences matérielles pour les joints utilisés dans les canalisations et les raccords véhiculant des combustibles gazeux et des hydrocarbures liquides*

ISO 16111:2018, *Appareils de stockage de gaz transportables – Hydrogène absorbé dans un hydrure métallique réversible*

ISO 17268, *Dispositifs de raccordement pour le ravitaillement des véhicules terrestres en hydrogène gazeux*

ISO 19881, *Hydrogène gazeux – Réservoirs de carburant pour véhicules terrestres*

ISO 19882, *Hydrogène gazeux – Dispositifs limiteurs de pression thermiquement activés pour les conteneurs de carburant de véhicules à hydrogène comprimé*

ISO 20898, *Chariots de manutention – Exigences électriques*

ISO 21927-3, *Systèmes de contrôle de fumée et de chaleur – Partie 3: Spécifications pour les ventilateurs mécaniques d'évacuation des fumées et de la chaleur*

ISO 23551-1, *Dispositifs de commande et de sécurité pour brûleurs à gaz et appareils à gaz – Exigences particulières – Partie 1: Robinets automatiques et semi-automatiques*

RTM ONU n° 13, *Règlement technique mondial sur les véhicules à hydrogène et à pile à combustible*

Règlement ONU n° 134, *Prescriptions uniformes relatives à l'homologation des véhicules automobiles et de leurs composants en ce qui concerne les prescriptions de sécurité des véhicules fonctionnant à l'hydrogène*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions donnés dans l'IEC 60050-485, ainsi que les suivants, s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.1
fonctionnement anormal
fonctionnement du système à pile à combustible avec dysfonctionnement ou défaillance d'un quelconque élément mécanique, électrique ou de commande, en tout mode de défaillance considéré comme raisonnablement probable dans l'analyse des modes de défaillance et de leurs effets (AMDE) à l'exclusion cependant de toute rupture ou panne accidentelle des conteneurs de liquides, vapeurs et/ou gaz inflammables

3.2
liaison équipotentielle
assemblage permanent de parties conductrices de manière à constituer un chemin électriquement conducteur positif assurant une continuité électrique entre parties conductrices et capable de conduire tout courant de défaut éventuel

Note 1 à l'article: Ceci s'applique à la liaison au sein du système à pile à combustible, ainsi qu'entre le système à pile à combustible et le chariot; il n'est pas fait référence aux moyens de mise à la terre du chariot proprement dit, par exemple avec un ruban de mise à la terre ou par l'intermédiaire des pneumatiques.

3.3
clapet antiretour
dispositif de régulation des fluides qui permet aux fluides de s'écouler dans une seule direction

3.4
circuit à puissance limitée
circuit qui implique un potentiel supérieur à 42,4 V crête (30 V efficace) ou 60 V en courant continu et dont la puissance après 60 s de fonctionnement est conforme aux valeurs indiquées dans le Tableau 2B et le Tableau 2C de l'IEC 60950-1:2005 et de l'IEC 60950-1:2005/AMD2:2013

Note 1 à l'article: Un circuit qui présente une basse tension à la fois dans des conditions normales et de défaut unique est appelé circuit à très basse tension de sécurité (TBTS) dans l'IEC 60950-1.

3.5
circuit basse tension
circuit qui implique un potentiel crête en circuit ouvert d'au plus 42,4 V (30 V efficace) ou 60 V en courant continu alimenté par une batterie, une pile à combustible, un transformateur ayant une puissance de sortie assignée inférieure à 100 VA et une tension de sortie maximale au secondaire de 30 V en courant alternatif. ou en associant un transformateur et une impédance fixe qui, en tant que système, est conforme à l'IEC 61558-1

Note 1 à l'article: Un circuit obtenu en connectant une résistance en série avec un circuit d'alimentation en tension comme moyen de limitation de la tension et du courant n'est pas considéré comme un circuit basse tension.

3.6
limite de zone de dilution
étendue d'une région ou d'une zone inflammable générée par un dégagement limité de gaz inflammable, interne au système à pile à combustible ou au chariot dans lequel le système est monté et contrôlé par une ventilation mécanique ou autre moyen efficace

Note 1 à l'article: Ceci est décrit dans l'IEC 60079-10-1.

3.7
décharge électrostatique
DES
transfert de charge électrique entre des corps aux potentiels électrostatiques différents à proximité ou par contact direct

[SOURCE: IEC 60050-561:2014, 561-03-06]

3.8
système à pile à combustible
système générateur qui utilise un ou plusieurs modules à pile à combustible pour produire de l'énergie électrique et de la chaleur

Note 1 à l'article: La Figure 1 représente le schéma de principe d'un système à pile à combustible. Le système à pile à combustible destiné à être utilisé avec des chariots apparaît dans l'une des formes indiquées en 3.9 et en 3.10.

[SOURCE: IEC 60050-485:2020, 485-09-01, modifié: ajout de la nouvelle note à l'article]

3.9
système autonome
système complet intégré dans son enveloppe propre, destiné à remplacer ou à être associé à un système de batterie pour alimenter un chariot de manutention

Note 1 à l'article: Les fonctions d'affichage et de contrôle peuvent être situées à l'extérieur de l'enveloppe du système à proximité du compartiment de l'opérateur. Cependant, si un contrepoids est nécessaire à l'extérieur de l'enveloppe du système ou si une communication directe est exigée entre le système et le contrôleur du chariot, il sera considéré comme un système intégré (voir 3.10).

3.10
système à pile à combustible intégré
ensemble d'un système d'organes et de pièces de piles à combustible incorporé dans le chariot de manutention avec les différentes parties du système éventuellement réparties sur tout le chariot

3.11
zone dangereuse
toute zone ou espace de travail où des poussières combustibles, des fibres inflammables ou des composés liquides, du gaz ou des mélanges inflammables ou volatils sont ou peuvent être présents dans l'air en quantités suffisantes pour produire des mélanges explosifs ou inflammables comme défini dans l'IEC 60079-10-1

3.12
intégré
ce qui est contenu soit à l'intérieur, soit à l'extérieur du système à pile à combustible, mais qui fait partie dudit système à pile à combustible

3.13
limite inférieure d'inflammabilité
LFL
concentration minimale de combustible dans un mélange combustible-air pour laquelle une combustion peut être initiée par une source d'inflammation

Note 1 à l'article: Un mélange combustible-air est inflammable lorsque la combustion peut être déclenchée par une source d'inflammation. Les proportions ou la composition du mélange combustible-air constituent la composante principale. Un mélange qui contient une quantité de combustible inférieure à la quantité critique dite limite inférieure d'inflammabilité (LFL), ou une quantité supérieure à la quantité critique dite limite supérieure d'inflammabilité (UFL), ne sera pas inflammable.

Note 2 à l'article: L'abréviation "LFL" est dérivée du terme anglais développé correspondant "lower flammability limit"

3.14
pression de service admissible maximale
PSMA
pression relative maximale à laquelle une cellule élémentaire à combustible ou un système à pile à combustible peut fonctionner

Note 1 à l'article: Voir un tableau comparatif des termes relatifs à la pression à l'Annexe A.

Note 2 à l'article: La pression de service admissible maximale est exprimée en Pa.

Note 3 à l'article: La pression de service admissible maximale est la pression utilisée pour déterminer l'emplacement des dispositifs de limitation/diminution de pression installés pour protéger un élément ou un système d'une surpression accidentelle.

[SOURCE: IEC 60050-485:2020, 485-17-03, modifié: ajout de la nouvelle Note 1 à l'article]

3.15
pression de service maximale
MOP
pression relative la plus élevée d'un organe ou du système susceptible d'apparaître en fonctionnement normal

Note 1 à l'article: Voir un tableau comparatif des termes relatifs à la pression à l'Annexe A.

Note 2 à l'article: L'abréviation "MOP" est dérivée du terme anglais développé correspondant "maximum operating pressure".

3.16
dégagement normal
valeur limite des volumes présents localement de concentrations d'hydrogène dégagées en fonctionnement normal, y compris éventuellement les purges de piles à combustible

3.17
fonctionnement normal
tout mode, en fonctionnement et hors fonctionnement, rencontré pendant l'utilisation du produit et qui ne résulte pas d'un dysfonctionnement ou d'une défaillance

3.18
dispositif limiteur de pression (dispositif de décharge de pression)
PRD
dispositif déclenché par la pression et/ou la température, utilisé pour éviter que la pression ne dépasse une valeur maximale préétablie et par conséquent prévenir la défaillance d'une pièce ou d'un système sous pression

Note 1 à l'article: L'abréviation "PRD" est dérivée du terme anglais développé correspondant "pressure relief device".

3.19
dispositif limiteur de pression à activation thermique
TPRD
dispositif limiteur de pression (3.18) qui est activé thermiquement

Note 1 à l'article: L'abréviation "TPRD" est dérivée du terme anglais développé correspondant "thermally activated pressure relief device".

3.20
appréciation du risque
processus englobant une analyse du risque et une évaluation du risque

3.21
analyse du risque
utilisation des informations disponibles pour identifier les phénomènes dangereux et estimer le risque

3.22
évaluation du risque
procédure fondée sur l'analyse du risque pour décider si le risque tolérable est atteint

3.23
dispositif de commande de sécurité
dispositif de commande automatique et de verrouillage qui comprend les relais, commutateurs, capteurs et autres équipements auxiliaires utilisés conjointement avec ces derniers pour constituer un système de commande de sécurité, destiné à prévenir un fonctionnement contraire à la sécurité du matériel contrôlé

3.24
élément critique du point de vue de la sécurité
organe, dispositif, circuit, logiciel ou pièce similaire dont la défaillance pourrait affecter la sécurité du système à pile à combustible, comme déterminé en 4.16

3.25
pression de service
pression de service nominale
pression, telle que spécifiée par le fabricant, à une température de gaz uniforme de 15 °C, le réservoir étant plein

Note 1 à l'article: Ce terme fait uniquement référence au réservoir d'hydrogène sous pression.

Note 2 à l'article: Voir un tableau comparatif des termes relatifs à la pression à l'Annexe A.

3.26
système de classification de zones
moyens de classement des zones dans le système à pile à combustible, utilisant les méthodes décrites dans l'IEC 60079-10-1

4 Exigences de construction en matière de sécurité

4.1 Généralités

Tout élément d'un produit couvert par le présent document doit être conforme aux exigences applicables audit élément. Les références normatives traitant des éléments utilisés dans les produits faisant l'objet du présent document sont indiquées à l'Article 2.

Il n'est pas exigé qu'un élément soit conforme à une exigence spécifique des normes citées en références normatives qui:

– concerne une fonction ou une caractéristique non exigée par l'application de l'élément dans le produit du présent document;
– est annulée et remplacée par une exigence du présent document; ou
– fait l'objet d'un examen distinct lorsqu'il fait partie d'un autre élément, à condition que l'élément soit utilisé dans le respect de ses caractéristiques assignées et limites établies.

Tout élément doit être utilisé conformément à ses valeurs assignées établies dans des conditions d'utilisation prévues.

Les éléments spécifiques sont incomplets en matière de caractéristiques de construction ou limités en matière de performance. Ils sont prévus pour être uniquement utilisés dans des conditions limitées, telles que certaines températures qui ne dépassent pas les limites spécifiées et ne doivent être utilisés que dans lesdites conditions spécifiques.

Un élément qui est également destiné à remplir d'autres fonctions telles que la protection contre les surintensités, l'interruption de circuits en défaut à la terre, la limitation de surtension, toute autre fonction similaire, ou toute combinaison de celles-ci, doit en outre être conforme aux exigences de la norme applicable qui couvre les dispositifs assurant ces fonctions.

4.2 Parties contenant de l'hydrogène et autres fluides

4.2.1 Généralités

Les parties sous pression ou contenant des fluides doivent résister à l'action des fluides.

Les parties métalliques contenant de l'hydrogène doivent être résistantes à la fragilisation par l'hydrogène, conformément à l'ISO/TR 15916. Si un matériau différent de ceux décrits dans l'ISO/TR 15916 est utilisé, une évaluation de la susceptibilité à la fragilisation par l'hydrogène est à effectuer conformément à l'ISO 11114-4 ou à l'ISO 2626.

Lorsque la corrosion atmosphérique d'une pièce contenant des fluides interfère avec sa fonction prévue, ou entraîne une fuite externe du fluide qui crée une situation dangereuse, ladite pièce doit être réalisée en matériau résistant à la corrosion ou être pourvue d'un revêtement de protection résistant à la corrosion.

Les pièces en élastomère ayant une fonction de sécurité telle que l'étanchéité à des fluides autres que l'hydrogène et susceptibles de générer une situation dangereuse en cas de fuite (par exemple un joint entre des pièces électriques et des pièces mouillées), doivent convenir à l'application prévue, conformément aux spécifications de l'ISO 1419, de l'ISO 1421, de l'ISO 13226, de l'ISO 16010 et de l'ISO 4675, selon le cas.

Toute pièce en élastomère employée pour assurer l'étanchéité de l'hydrogène doit convenir à l'utilisation avec de l'hydrogène. Les références et lignes directrices de l'ISO/TR 15916 doivent être prises en compte pour les matériaux élastomères. La résistance à la traction et à l'allongement du matériau doit être évaluée à l'état de réception puis après vieillissement en étuve (sur la base des températures de service) conformément à 5.20.

4.2.2 Tuyauteries, flexibles, tubulures et raccords

1) Lorsqu'elles transportent des gaz à des pressions relatives supérieures à 103,4 kPa ou des liquides à des pressions supérieures à 1 103 kPa ou à des températures supérieures à 120 °C, les tuyauteries et les pièces accessoires correspondantes doivent être conçues, fabriquées et soumises aux essais conformément aux spécifications applicables de l'ISO 15649.
2) Les tuyauteries utilisées à des niveaux de pression et/ou à des températures inférieurs à ceux indiqués en 1), ainsi que les tuyauteries non métalliques, doivent être évaluées au vu des exigences du présent document, en tenant dûment compte des matériaux et fluides contenus, ainsi que des conditions de service, y compris les pressions et les températures. Les tuyauteries non métalliques transportant du combustible hydrogène ou méthanol gazeux doivent être conçues, fabriquées et soumises aux essais conformément aux exigences supplémentaires de 6).
3) Les flexibles non métalliques utilisés pour du combustible hydrogène ou méthanol gazeux, situés à l'extérieur du système à pile à combustible et soumis à des contraintes physiques, doivent satisfaire aux essais hydrostatiques, d'adhérence (caoutchouc uniquement), de souplesse, de souplesse à faible température, de résistance à l'ozone (pour les flexibles comportant un couvercle de protection extérieur en caoutchouc), de résistance aux UV (pour les flexibles recouverts de matière plastique), de perméabilité aux gaz, de conductivité électrique; ainsi qu'aux essais d'intégrité des raccords, tels que décrits dans l'ISO 14113. Les matériaux doivent convenir à une utilisation avec du combustible hydrogène ou avec le fluide contenu (c'est-à-dire le méthanol), conformément à 4.2.1. Les flexibles d'une longueur supérieure à 1,5 m doivent être renforcés par une tresse en fil d'acier inoxydable.
4) Les connecteurs en métal souples, ainsi que les raccords correspondants, lorsqu'ils sont utilisés pour transporter de l'hydrogène gazeux, doivent être conformes à l'ISO 10806 et à l'ISO 10380, tel qu'exigé.
5) Une canalisation de combustible hydrogène doit être soutenue de manière à réduire le plus possible l'usure par frottement et de la maintenir à une distance d'au moins 51 mm de l'échappement et des parties du système électrique.
   a) Les équipements électriques et les capteurs dans les circuits à puissance limitée qui n'ont pas assez d'énergie électrique pour endommager une conduite de carburant ne sont pas tenus de se conformer à cette exigence.
   b) S'il peut être démontré que les canalisations de combustible et le câblage sont suffisamment soutenus pour empêcher que la distance ne soit réduite à moins de 12,7 mm, la distance entre les canalisations de combustible et les parties du système électrique peut être réduite.
6) Les canalisations non métalliques de combustible hydrogène et méthanol doivent:
   – être protégées dans des enceintes ventilées, dans lesquelles toutes les contraintes mécaniques ou physiques sont réduites au minimum;
   – être conductrices pour éviter les décharges électrostatiques. La conformité est déterminée par l'essai de continuité de 5.10 2) pour les canalisations de combustible métalliques, et de 5.10 3), pour les canalisations de combustibles non métalliques;
   – être constituées de matériaux évalués comme étant appropriés pour les fluides qu'elles transportent, en tenant dûment compte des températures auxquelles elles sont exposées en service. La conformité doit être déterminée comme décrit en 5.20 et 5.21, selon le cas; et
   – être conformes aux exigences DES définies dans l'ISO 4038 lorsqu'elles sont connectées entre le circuit de combustible et la pile.
7) Les tuyauteries, tubulures, raccords et autres éléments de tuyauterie doivent pouvoir supporter un essai hydrostatique à une pression égale à au moins 1,5 fois la pression de

service assignée sans présenter de défaillance structurelle. Les tuyauteries, tubulures, raccords et autres éléments de tuyauterie haute pression doivent avoir une marge de sécurité équivalente à la bouteille de stockage utilisée. Voir 4.2.3.

4.2.3 Réservoirs d'hydrogène sous pression

1) Les réservoirs sous pression doivent être spécifiquement conçus pour les conditions de service de l'application chariot de manutention, ce qui inclut le nombre maximal de cycles de remplissage prévus, les plages de pression et de température prévues en fonctionnement et lors du remplissage, l'effet de l'hydrogène sur la durée de vie en fatigue, ainsi que la fréquence des contrôles.
2) En référence à 1), un réservoir sous pression doit être conçu, fabriqué et soumis aux essais, en tenant compte des conditions et restrictions suivantes:
   a) le conteneur de la catégorie C définie dans l'ISO 19881 doit s'appliquer;
   b) s'agissant des réservoirs de Type 1, ils doivent être conçus et soumis à essai conformément à l'ISO 19881;
   c) dans la version anglaise, le terme "working pressure" ("pression de service") du réservoir, comme défini dans l'ISO 19881, est identique au terme "service pressure" (même signification) du présent document;
   d) s'agissant des réservoirs de Type 3 et du Type 4, ils doivent être conçus et soumis à essai conformément à l'ISO 19881, au RTM ONU n° 13 et au règlement ONU n° 134;
   e) le réservoir doit être conçu pour la durée de vie prévue du système à pile à combustible et pour au moins 11 250 cycles de remplissage complets.

      NOTE "11 250 cycles de remplissage complets", c'est-à-dire 3 remplissages/jour, 365 jours/an, 10 ans = 10 950 cycles.
3) Un réservoir sous pression et un raccord de remplissage doivent être placés dans le périmètre d'encombrement du chariot de manutention ou dans une enceinte telle que définie en 4.13, et situés de façon à réduire toute possibilité d'endommagement du réservoir ou des raccords utilisés pour le transport d'hydrogène.
4) Un limiteur de débit et un clapet antiretour, éventuellement, doivent être directement raccordés au réservoir sous pression ou montés sur la même canalisation que lui, en un lieu où il n'existe pas de dispositif de fermeture entre le réservoir sous pression et le clapet antiretour, de manière à réduire au minimum les effets négatifs des chocs et vibrations, ainsi que les éventuels dommages accidentels.
5) La canalisation de ravitaillement des circuits doit être équipée d'un clapet antiretour, assurant une fonction redondante par rapport à celle du clapet antiretour du récipient spécifié dans l'ISO 17268.
6) Les réservoirs sous pression doivent disposer d'un moyen de vidange (dépressurisation) et de purge d'hydrogène utilisant un gaz inerte, comme souligné dans les instructions d'utilisation ou dans le manuel de maintenance, selon le cas, fourni avec le système à pile à combustible.
7) Un robinet manuel permettant d'isoler l'alimentation en combustible doit être placé à proximité du réservoir sous pression, de façon à ce que l'alimentation en combustible vers le système à pile à combustible puisse être fermée pour maintenance ou pour stockage à long terme.
8) Le réservoir d'hydrogène sous pression doit être monté à demeure sur le module du système à pile à combustible ou sur le chariot de manutention, afin de s'assurer que le réservoir sous pression ne quitte pas son logement en cours d'utilisation ou ne puisse pas être déposé en cas de ravitaillement.

4.2.4 Conteneur en hydrure métallique

Les systèmes de stockage de combustible hydrogène dans un hydrure métallique doivent être conformes à l'Article 4, à l'Article 5 et à l'Article 6 de l'ISO 16111:2018.

4.2.5 Réservoir de combustible méthanol

1) Les réservoirs de combustible méthanol doivent être construits en matériaux appropriés conformément à 4.2.1 et à 4.2.2 et doivent satisfaire aux exigences indiquées ci-dessous. Ces réservoirs, ainsi que les joints d'étanchéité et raccords correspondants, doivent être conçus et construits avec une résistance qui convient à la fonctionnalité prévue et une résistance aux fuites évitant tout dégagement non intentionnel.
2) Les réservoirs de combustible méthanol doivent être spécifiquement conçus pour les conditions de service de l'application chariot de manutention qui couvre les plages de pression et de température prévues en fonctionnement et lors du remplissage, l'effet du méthanol sur la durée de vie en fatigue du réservoir et les fréquences des contrôles.
3) Un robinet manuel permettant d'isoler l'alimentation en combustible doit être placé à proximité du réservoir de combustible, de façon à ce que l'alimentation en combustible vers le système à pile à combustible puisse être fermée pour maintenance ou pour stockage à long terme.
4) Un réservoir de combustible méthanol et un raccord de remplissage doivent être situés dans l'encombrement du chariot de manutention ou dans une enceinte telle que définie en 4.13, et situé de façon à réduire toute possibilité d'endommagement du réservoir ou des raccords utilisés pour le transport d'hydrogène.
5) Le réservoir de combustible méthanol doit être monté à demeure sur le module du système à pile à combustible ou sur le chariot de manutention, afin de s'assurer que le réservoir ne quitte pas son logement en cours d'utilisation ou ne puisse pas être déposé en cas de ravitaillement.

4.3 Ravitaillement

L'interface de ravitaillement doit correspondre à la pression assignée du conteneur (voir 4.2.3 2)c)) et doit être conforme à l'ISO 17268.

4.4 Protection contre les surpressions et protection thermique

1) Le réservoir d'hydrogène sous pression doit être protégé contre les effets du feu par un dispositif limiteur de pression à activation thermique (TPRD) sans refermeture, conçu, fabriqué et soumis aux essais conformément à l'ISO 19882.
2) Les éléments et tuyauteries situés en aval d'un réducteur de pression dont le réglage assigné est inférieur à la pression d'admission maximale du réducteur de pression, doivent être protégés contre les surpressions en cas de défaillance du réducteur de pression au moyen d'un dispositif limiteur de pression.
3) Les dispositifs limiteurs de pression doivent convenir à l'application correspondante, y compris pour ce qui concerne les matériaux en contact avec l'hydrogène, ainsi que les pressions et débits assignés.
4) Les dispositifs limiteurs de pression fonctionnant à des pressions supérieures à 1 000 kPa doivent être dimensionnés et conçus de manière à limiter la pression en cas de défaut à moins de 110 % de la pression de service maximale admissible. La refermeture ne doit pas avoir lieu à moins de 90 % du point de consigne. Les dispositifs limiteurs de pression fonctionnant à des pressions inférieures ou égales à 1 000 kPa doivent être dimensionnés et conçus de manière à limiter la pression en cas de défaut à moins de 125 % de la pression de service maximale admissible. La refermeture ne doit pas avoir lieu à moins de 90 % du point de consigne. Le module de pile à combustible doit être protégée conformément à l'IEC 62282-2-100.
5) Lorsqu'elle est fournie, la tuyauterie de décharge de la limitation de pression doit être dimensionnée de manière à assurer la conformité à 4.4 4).
6) La décharge d'un dispositif limiteur de pression donné doit être placée de façon à ce que le fonctionnement du dispositif n'entraîne pas de situation dangereuse, telle que:
   a) le dégagement d'hydrogène gazeux à plus de 25 % de la limite inférieure d'inflammabilité (LFL) vers une zone non classée ou à pression confinée dans le système à pile à combustible. La décharge du dispositif limiteur de pression peut être placée dans l'encombrement du système à pile à combustible en utilisant une ventilation

adéquate ou en mettant en œuvre un système de commande de sécurité adéquat constitué d'un capteur d'hydrogène et d'un dispositif d'arrêt d'hydrogène obturant la fuite en cas de détection;

b) un dépôt d'humidité sur des parties sous tension, susceptible de créer un risque de choc électrique;

c) des objets étrangers, de l'humidité ou des débris, qui pourraient entrer dans le système de ventilation non protégé par des capots, des couvercles ou autres;

d) un risque pour que le système de ventilation ne soit plus fixé ou qu'il soit retiré de manière à affecter la trajectoire du débit; ou

e) le dégagement de pression soit dirigé ou dévié vers la position normale de l'opérateur.

7) Un orifice de mise à l'air libre du dispositif limiteur de pression doit être fixé à intervalles réguliers, de manière à réduire la possibilité d'endommagement, de corrosion ou de rupture de la canalisation de mise à l'air libre ou du dispositif limiteur de pression du fait de la dilatation, de la contraction, des vibrations, des contraintes ou de l'usure et d'éviter tout desserrage en fonctionnement.

8) Le système de mise à l'air libre, y compris le raccord de sortie du dispositif limiteur de pression et des canalisations de mise à l'air libre correspondantes, doit être conçu de manière à supporter la pression maximale développée pendant le fonctionnement à plein débit du dispositif limiteur de pression sans qu'il ne soit séparé de ses fixations. S'il est prévu, le bouchon de mise à l'air libre doit être fixé par mesure de sécurité.

9) Les dispositifs limiteurs de pression, représentés dans les exemples des Figure 2, Figure 3 et Figure 4, doivent être conformes à l'ISO 15649.

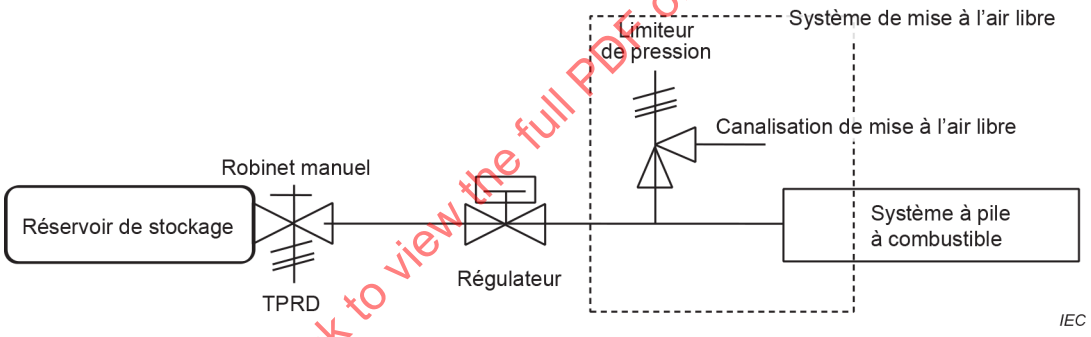


Figure 2 – Exemple schématique d'un système de mise à l'air libre pour des éléments en aval du régulateur

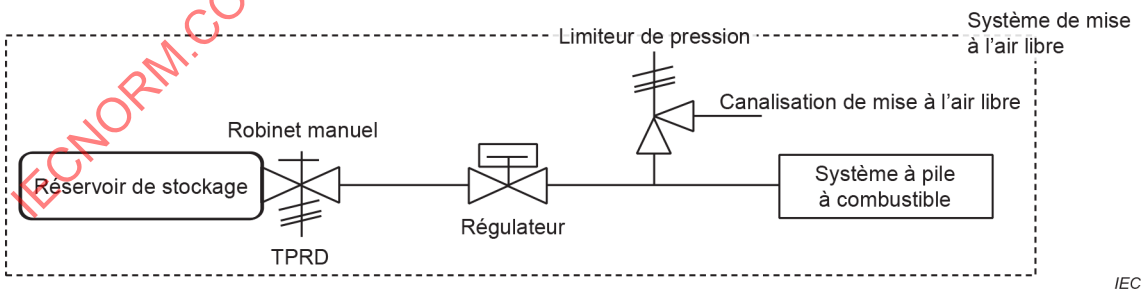


Figure 3 – Exemple schématique d'un système de mise à l'air libre pour tous les éléments

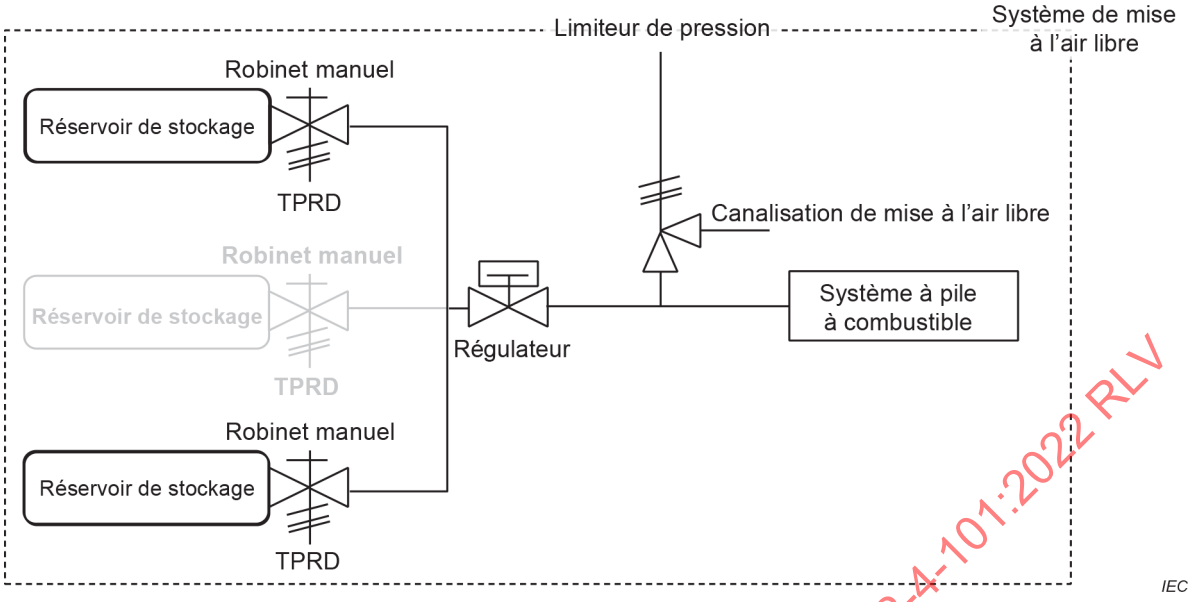


Figure 4 – Exemple schématique d'un système de mise à l'air libre pour tous les éléments dans un système à plusieurs réservoirs de stockage

4.5 Régulateurs

Le régulateur de pression de gaz doit être équipé d'un limiteur de débit ou d'une canalisation de mise à l'air libre.

4.6 Robinets de commande et d'arrêt

1) Les vannes et robinets doivent avoir les caractéristiques assignées conformes à l'application, y compris en matière de pression, de température ou de fluides en contact et de valeurs assignées électriques, le cas échéant.
   a) Les électrovannes doivent être conformes à l'ISO 23551-1.
   b) Les robinets pour tuyauteries haute pression doivent être soumis à essai conformément à l'ISO 15649, au lieu de l'essai de fuites externes et l'épreuve de résistance hydrostatique de l'ISO 23551-1.
   c) Les robinets pour fluides inflammables doivent être conformes à l'ISO 23551-1.
2) Les combustibles alimentant le système à pile à combustible doivent être fournis par des canalisations de combustible équipées d'au moins un robinet d'arrêt automatique de sécurité. Le robinet d'arrêt de sécurité peut également être un robinet de commande. Le temps de fermeture d'un robinet d'arrêt de sécurité ne doit pas être supérieur à 5 s.
3) Si un robinet manuel d'arrêt d'urgence est considéré comme nécessaire selon 4.16, il doit être situé en un emplacement facilement accessible qui ne doit pas nécessiter une rotation supérieure à 90° de la position ouverte à la position fermée. Une clé ou un outil ne doit pas empêcher l'accès au robinet d'arrêt manuel. Le robinet doit être monté à demeure et blindé ou installé en un lieu protégé afin de réduire les éventuels dommages dus à des vibrations ou à des chocs.
4) Lorsqu'un robinet manuel est utilisé, il doit comporter un marquage conforme à l'Article 7 3)f).
5) Les robinets d'arrêt électriques, automatiques et autres doivent, en cas de défaillance, retourner à une position de sécurité (sécurité intrinsèque).
6) Les électrovannes placées dans des zones classées doivent être conçues pour la zone de classification considérée.

4.7 Filtres

Les filtres à air et à fluide doivent convenir à l'application et être facilement accessibles s'il est exigé de les contrôler, de les nettoyer ou de les remplacer.